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ORIGINAL ARTICLES.

I. — Eminent Living Geologists: The Rev. P. B. Brodie, M.A., F.G.S.[1]

(WITH A PORTRAIT, PLATE XX.)

THE REV. PETER BELLINGER BRODIE was born in London in 1815. His father, Mr. P. B. Brodie, was an eminent conveyancer and barrister-at-law, while his uncle, Sir Benjamin C. Brodie, Bart., the celebrated surgeon, was President of the Royal Society from 1858 to 1861.

While a youth, and resident with his father at Lincoln's Inn Fields, the younger P. B. Brodie acquired a taste for Natural History, and often went as a student to the Royal College of Surgeons. Geology, in these early years, attracted his attention, and to such good effect, that he was proposed as a Fellow of the Geological Society of London by William Clift, the Curator of the College of Surgeons, and he was elected so long ago as January, 1834, just before he went to Cambridge. At that time he was the youngest Fellow ever admitted; now he remains one of the oldest, and, with one exception, the earliest elected of the present Fellows of the Society. H. E. Strickland, with whom in after years Mr. Brodie was much associated, was elected into the Geological Society towards the end of the same year, 1834, and during the Presidency of G. B. Greenough. At this time, Buckland and Conybeare, Sedgwick, De la Beche and Fitton, Murchison and Lyell, were all members of the Council. As Mr. Brodie tells us, he then attended meetings of the Society held in Somerset House, and listened to "many intellectual combats between the geological giants of those days."

Educated afterwards at Emmanuel College, Cambridge, he naturally came under the inspiriting influence of Sedgwick. He regularly attended the lectures of the famous Professor, and voluntarily assisted him in the Woodwardian Museum. Thus Mr. Brodie's early interest in Geology was fostered, and he soon began to

[1] Some of the particulars given in this brief biography were kindly furnished by the Rev. P. B. Brodie, and others by Mr. S. S. Stanley.

undertake original work. His first paper, "Notice on the occurrence of Land and Fresh-water Shells with Bones of some Extinct Animals in the Gravel near Cambridge," was read in 1838 before the Cambridge Philosophical Society, but it was not printed until six years afterwards.[1] Some notes were contributed to this paper by Sedgwick, and it contained the earliest published record of the Mollusca from the now celebrated Pleistocene deposit of Barnwell.

In 1838 Mr. Brodie was ordained deacon, and the same year he was appointed curate to the rector of Wylye, in Wiltshire. The village is situated on the south-western borders of Salisbury Plain, and about four miles to the north of Dinton, in the Vale of Wardour. Here it was that Mr. Brodie became acquainted with that interesting geological region, and his researches added further renown to a district already made famous by the observations of Miss Benett and Dr. Fitton.

In May, 1839, Mr. Brodie read his first paper before the Geological Society of London, entitled "A notice on the discovery of the remains of Insects, and a new genus of Isopodous Crustacea belonging to the family Cymothoidæ, in the Wealden Formation in the Vale of Wardour, Wilts" (Proc. Geol. Soc., iii, 134). The new Isopod was determined by Professor Owen, and subsequently described by Milne-Edwards under the now familiar name of *Archæoniscus Brodiei*. The strata, in one layer of which this fossil occurs in profusion, have since been grouped with the Purbeck Beds.

Mr. Brodie was admitted to priest's orders in 1839, and he stayed barely two years in his Wiltshire parish. In 1840 he became curate to the vicar of Steeple Claydon, in Buckinghamshire, and entered a region of Oxford Clay and Drift in the vale of Bicester, and a famous hunting country. Steeple Claydon is about four miles south of Buckingham, where the Lower Oolites come to the surface; but Mr. Brodie's observations were directed to the country further south, where he found at Quainton Hill, and at Stone, near Aylesbury, outliers of Portland and Purbeck beds possessing "a certain similarity with those in Wiltshire, but with clearly marked local differences." Staying but a few months at Steeple Claydon, his discovery of remains of Insects and other fossils in the "Wealden" (Purbeck) strata of Buckinghamshire was published after he had left the district (Proc. Geol. Soc., iii, 780).

In 1841 Mr. Brodie was appointed Rector of Down Hatherley in the Vale of Gloucester, and about five miles west of Cheltenham. Here he came into a richly fossiliferous region of Lias and Oolites, and here he had also the advantage of many fellow workers in geology. Strickland's home at Cracombe House, Evesham, was not far away to the north, and those of Dr. Wright and James Buckman lay a few miles to the east. W. S. Symonds, afterwards Rector of Pendock, was from 1843–5 Curate of Offenham, near Evesham; and Lycett must about this time have commenced his labours at Minchinhampton. It was not long before Mr. Brodie announced his discovery of Insect-remains in the Lower Lias in Gloucestershire,

[1] Trans. Cambridge Phil. Soc., viii, 138.

and he published sections of the basement-beds of that formation, and of the underlying strata (now grouped as Rhætic), which he had studied at Wainlode and Westbury-on-Severn. He also in the same year (1842) drew attention to the occurrence of fossil plants in the so-called "Plastic Clay" of the cliffs at Bournemouth—a locality since famed for the many plant-remains obtained and described by Mr. Starkie Gardner.

In 1844 Mr. Brodie was associated with Professor Buckman in a paper on the Stonesfield Slate of the Cotteswold Hills, and, in addition to many stratigraphical details, the authors recorded from the deposit various Insects, Plant-remains, and other fossils. The researches thus carried on by Mr. Brodie opened up quite a new line of study—that of Fossil Insects. In 1845, assisted by Professor J. O. Westwood, he embodied his results in a work entitled "A History of the Fossil Insects in the Secondary Rocks of England." This included a particular account of the strata in which the remains were found; and the work was appropriately dedicated to his old Master, Sedgwick. The volume was the first ever published on the special subject of Fossil Insects. Later on, Mr. Brodie communicated to the Geological Society of London important papers on the Inferior Oolite of Cheltenham, and on the Purbeck Beds of Swindon.

Although not one of the original members of the Cotteswold Naturalists' Field Club, which was founded in 1846, Mr. Brodie soon joined its ranks. In 1850 he read before the Club a sketch of the Geology of Grantham, and in 1853 he communicated remarks on the Lias of Fretherne and Purton, and on certain Pleistocene Deposits in the Vale of Gloucester. It had been his intention "to have investigated the Pleistocene formation generally in Gloucestershire," but the duties of his calling led him away this same year (1853) to the Vicarage of Rowington, in Warwickshire. It was with great regret (as he tells us) that he left so picturesque and instructive a region as that which was embraced by the proceedings of the Cotteswold Club, and his sorrow was increased by the loss of their pleasant meetings, and the parting with many friends, whose companionship had added a charm and a zest to his studies. (Proc. Cotteswold Club, vol. i, p. 246.)

Rowington village, which now became the scene of Mr. Brodie's labours, is situated on the Keuper marls and sandstones, which are covered here and there by various Drift deposits. Fossils were no longer to be so readily obtained. Nevertheless, the Lower Lias was within reach at Wilmcote, some six or seven miles to the south, and an outlier of the same formation occurs near Knowle, about six miles to the north of Rowington. Mr. Brodie continued to devote his attention very much to the same lines of research, extending them at times to the Upper Silurian and passage-beds of Herefordshire, and recording the occurrence therein of *Eurypterus* and *Pterygotus*, as well as land-plants. He still contributed an occasional paper to the Cotteswold Club, on the Inferior Oolite and Lias of Northamptonshire, and on the Lias of Barrow in Leicestershire.

Warwickshire, however, naturally claimed his especial attention. Soon after his arrival at Rowington, he became a member of the Warwickshire Natural History and Archæological Society (founded in 1836), and he was at once elected an Honorary Curator of Geology in the Society's Museum at Warwick. Many years later (1894) he was elected President of this Society. Field-meetings were naturally regarded by Mr. Brodie as essential for the proper pursuit of natural history, and in 1854 he was the means of founding the Warwickshire Naturalists' and Archæologists' Field Club, of which he was the first Vice-President and Honorary Secretary. He was elected President in 1888. Mr. S. S. Stanley, who for some years acted as junior Honorary Secretary of the Warwickshire Field Club with Mr. Brodie, speaks of the new life and energy which the Vicar of Rowington infused among the naturalists and archæologists of Warwickshire. Foremost as a leader in field-excursions, he kindled in many others an interest in science, as much by his unfailing enthusiasm and good-humour as by his wide knowledge and experience.

In 1855, Mr. Brodie was appointed to the rectory of Baddesley Clinton, a neighbouring village to the north of Rowington; and, with the aid of his son, the Rev. F. M. Brodie, he has continued to discharge the many duties connected with his two parishes.

To the Proceedings of the Warwickshire Natural History Society, and of the Field Club, Mr. Brodie has contributed very numerous papers and addresses, dealing largely with the Keuper and Rhætic formations, the Lias, and various Drift deposits. Most important discoveries of Fish-remains, and also of Mollusca, in the Keuper formation of Warwickshire, have thus been recorded; while the tracts of Lower Lias on the borders of Shropshire and Cheshire, and in Cumberland, have not been unnoticed.

In 1858 Mr. Brodie contributed a series of articles on the Geology of Gloucestershire to the first volume of the *Geologist*, and since then he has sent many papers to the Geological Society, the British Association, and the Geological Magazine. Among these articles, those on the Purbeck Beds of Brill, and the Rhætic Beds near Wells, in Somerset, may be mentioned. So recently as August of the present year he sent a communication to be read at the field-meeting of the Warwickshire Naturalists' Club, held at Wilmcote.

In the course of his long life, Mr. Brodie has formed a most valuable and extensive geological collection, estimated to comprise upwards of 25,000 specimens. The rarer and unique examples have now been placed in the British Museum (Natural History), Cromwell Road; others have unfortunately been dispersed among foreign museums, and a considerable portion in one of our Colonies.

In 1887 the Murchison Medal was awarded to Mr. Brodie by the Council of the Geological Society, and at that date the President, Professor Judd, remarked: "Never, probably, has an award of this Society been made to one who can look back upon so long a record of faithful services to Geology as yourself. . . . . A dweller in the provinces, you have shown how the advancement of our science may best be promoted under those conditions."

The ten subsequent years have tended in no ways to decrease the enthusiasm which Mr. Brodie has ever manifested in the pursuit of geological science. Owing to advanced age, he has had lately to relinquish the office of rural dean of Warwick, which he held for many years; but we trust he may yet be spared some years longer for the tranquil enjoyment of his parochial work in the pleasant home at Rowington. H. B. Woodward.

II.—The Chalky Boulder-clay and the Glacial Phenomena of the Western-Midland Counties of England.[1]

By Horace B. Woodward, F.R.S., F.G.S.

THE extent of the glaciation in the Western-Midland Counties of England during the formation of the Chalky Boulder-clay has yet to be determined in detail. No accurate survey has at present been made of the various Drifts that are scattered over the country from Northamptonshire and Buckinghamshire on the east to Worcestershire and Gloucestershire on the west; but the observations of Strickland, Brodie, Lloyd, Lucy, and others, have made known the characters of the superficial deposits at numerous localities in and around the vale of Evesham, while the probable limit of the action of land-ice during the period of maximum glaciation has been delineated on a small map by S. V. Wood, jun.[2]

The district is of considerable interest as being on the borders of the large region which was mantled by the ice-sheet during the accumulation of the Chalky Boulder-clay of East Anglia; and it was not affected by any marked glaciation during the later phases of the Pleistocene period. The "Modified Drifts" which, in the form of valley-gravels and loams, succeeded the Boulder-clay, yield, as at Cropthorne, the Mammoth and associated fossils; and these deposits merge into the old estuarine and marine deposits of the great Severn Valley.

The probable southern limits of the Chalky Boulder-clay in England may be traced from Hornchurch in the Thames Valley to the north of London and Watford, and thence from the neighbourhood of St. Albans, round by Luton and Leighton Buzzard, into the vale of Aylesbury. A rough boundary may thence be traced between Bicester and Buckingham, to the north of Banbury, and into the vale of Moreton. Finally, the limits must be sought to the north of the Cotteswolds and Bredon Hill, the evidences of ice-action being discernible here and there in the vale of Evesham.

It is noteworthy that the elevated regions of Edge Hill and the Cotteswolds appear to have arrested the progress of land-glaciation. This seems also to have been the case along the higher parts of the Chiltern range, from Wendover to Tring and Dunstable, and these elevated Chalk areas are indeed marked by S. V. Wood, jun., as having been free from the ice which formed the Chalky Boulder-clay. In other places, as along the Liassic scarp near Catesby in

[1] Read before the Meeting of the British Association at Toronto.

[2] Quart. Journ. Geol. Soc., vol. xxxviii, map 4, pl. xxvi.

Northamptonshire, and in certain Midland areas, there is a local absence of Boulder-clay and of signs of glaciation—an absence not always to be attributed to subsequent denudation, but rather suggesting that the margin of the ice-sheet was prolonged here and there into tongues or broad lobes, as in the vale of Moreton, the low grounds near Buckingham, and the lower areas of Chalk and Tertiary strata in Hertfordshire.

Prior to the formation of the Chalky Boulder-clay in the more central portions of England, we may picture an area whose main features did not differ very largely from those of the present time. The stonebrash hills, in the now glaciated tracts, may have stood out somewhat more prominently from the clay vales in the Jurassic areas, and the country was thickly coated with weathered rock or rubble. The Chalk areas were more extensively covered with clay-with-flints, and with outliers of Tertiary clays, sands, and gravels; while, over the barer tracts of Chalk, the rock itself was much broken up at the surface, and the loosened blocks were in places weathered into a somewhat rubbly form. Hence the greater portion of the land was covered with disintegrated rock and loose superficial strata, such as would readily be frozen into the base of a sedentary ice-sheet, if formed, as in North America, in the way so clearly depicted by Mr. W. O. Crosby.[1]

That the contents of the Chalky Boulder-clay vary to a noticeable extent in accordance with the nature of the strata over which the ice passed, is a well-established fact: nevertheless, the Boulder-clay maintains over a wide area its characteristic chalky ingredients.

It thus appears remarkably uniform in character in its extent from Norfolk to Essex, and from the Eastern Counties to Northamptonshire and Buckinghamshire—a feature mainly due to its abundant chalk and flint. More chalky in West Norfolk, it is more clayey in South Norfolk, Cambridgeshire, Suffolk, and Essex, where Kimeridge Clay and London Clay have been incorporated with other materials in the Boulder-clay. In Huntingdonshire the Oxford Clay, and in Northamptonshire the Lias Clay, have contributed to the Drift a marked amount of débris. A local character has likewise been imparted by the harder outcropping strata over which the Boulder-clay has been distributed.

Along the Midland branch-railway between Bourn and Saxby, very fine cuttings of Chalky Boulder-clay were opened up. The country was trenched in an east-and-west direction from the Oxford Clay of Bourn to the Lower Lias near Melton Mowbray. Amongst the Jurassic materials in the Boulder-clay there was a noteworthy preponderance of Oxfordian fossils in the eastern, of Great Oolite fossils in the central, and of Lias fossils in the western portion of the area.[2]

Cuttings along the new London extension of the Manchester, Sheffield, and Lincolnshire Railway (now termed the Great Central

[1] Geol. Mag. 1897, p. 321: abridgment of article on Englacial Drift in *Technology Quarterly*, vol. ix, Boston.

[2] H. B. W., "Jurassic Rocks of Britain," vol. iv, p. 422.

Railway), have trenched the country in a north-and-south direction, and very fine sections of Chalky Boulder-clay were exposed between Catesby and Quainton Road, near Aylesbury. The Middle Lias fossils were noteworthy ingredients of the Boulder-clay in the north, and those of the Oxford Clay in the south. In none of these cuttings were there exposed any very large boulders or "cakes" of Secondary rock.

Chalky Boulder-clay occurs in various parts of Warwickshire. It was recognized near Rugby by S. V. Wood, jun.,[1] and in other localities by the Rev. P. B. Brodie[2] and by Mr. W. Andrews.[3] T. G. B. Lloyd[4] observed purple-coloured Boulder-clay containing Chalk, etc., on the Lower Lias area in north-east Warwickshire; and it is likely that in this county, as elsewhere, coloured clays from the New Red Series have been disseminated with other materials in the Boulder-clay.

The most distant evidence of Boulder-clay in the south-western region is that to which attention was directed in 1853 by Mr. G. E. Gavey.[5] The Drift, comprising Boulder-clay, gravel, and sand, was exposed in the railway-cuttings at Aston Magna and Mickleton, and at the time Mr. R. F. Tomes obtained glaciated Chalk from this Drift.[6] In connection with the discovery, it is interesting to note that pebbles of hard red and white Chalk were found by Buckland in 1821, to the south-east of Shipston-on-Stour.[7]

It may be remarked that the "Boulder-clay" to which Mr. W. C. Lucy has called attention as occurring on the Cotteswold plateau, is simply clay with "Northern Drift" pebbles. It occurs in pockets or fissures of the Inferior Oolite here and there, but in itself it affords no evidence of glaciation. Moreover, the so-called "Northern Drift" in the lower portions of the Severn Vale is reassorted, and no doubt derived its erratic pebbles from Boulder-clay in the upper parts of the Severn drainage-area.

To the north-west of Leafield, and at Combe near Woodstock, the higher elevations of Oxford Clay have a thin covering of soil with pebbles of quartz and quartzite. This gravelly soil lies irregularly on the clay, and penetrates it in hollows to a depth of three or four feet, having no doubt descended in cracks which have opened in the clay during very dry weather. Drift of this character affords no evidence of glaciation.

That the Cotteswolds themselves have not been glaciated, is shown by the thick accumulations of oolitic rubble which flank their slopes. Even the Bredon outlier of Inferior Oolite exhibits at the surface 30 or 40 feet of rubble. The rock, indeed, is irregularly weathered, and the resulting gravelly detritus contains in its midst isolated

[1] Quart. Journ. Geol. Soc., vol. xxvi, p. 224, and GEOL. MAG. 1870, p. 18.
[2] Quart. Journ. Geol. Soc., vol. xxiii, p. 209, and Rep. Brit. Assoc. for 1865, p. 49.
[3] Proc. Warwickshire Nat. Club for 1884, 1885, p. 32.
[4] Quart. Journ. Geol. Soc., vol. xxvi, pp. 205–6. See also A. H. W. Ingram, ibid., xxxv, p. 678.
[5] Quart. Journ. Geol. Soc., vol. ix, p. 29.
[6] Proc. Cotteswold Club, vol. vii, p. 60.
[7] Trans. Geol. Soc., vol. v, p. 518; Reliq. Diluv., 1823, p. 250.

masses and pinnacles of unweathered limestone. Some of the more remarkable accumulations of rubble occur to the north-west of Break Heart Hill, south of Dursley; near Gravel Farm, south of Harescomb; at Leckhampton Hill, where the rubble is banked up at angles of 30° or 40°; and west of Syreford, near Andoversford. Frequently there is a considerable thickness of brown loamy clay on top of the oolitic rubble—the residue of atmospheric waste, indicating some lapse of time.

This material has been described by Strickland, Hull, Lucy, Witchell, Prestwich, and others. Mr. Lucy connected the distribution of the rubble with soil-movements, the weathered rock slipping down the hill-sides during times of thaw after severe frost.[1] In Witchell's opinion, this Rubble Drift was "due to storm-waters or surface-drainage, which brought the detritus down the hill upon a frozen surface, and deposited it in those places where the frost usually disappeared in spring before it left the higher ground."[2] Both explanations may be to a certain extent true, and they accord much better with the facts than does the explanation of Prestwich, whereby this Rubble Drift would be due to the effects of wide submergence.[3]

In studying the general characters of the Glacial Drift, several problems of special interest come under notice. Among these are the abundance and wide distribution of chalky detritus; the disturbances produced in underlying strata; the occurrence of the larger blocks or "cakes" of local origin; and the intercalation of the gravels and sands with the Chalky Boulder-clay. If, following Crosby, we believe that the earlier action over the glaciated areas was the removal of the weathered soil and subsoil which was frozen to the base of the at first sedentary ice, we may conclude that the major disturbances in the underlying strata were then produced, together with the striated pavements which are very rarely, of course, to be found in these Midland areas. Although "drag" is not admitted as a likely mode of transport of the ground-moraine, yet, when this material was in movement at the base of the ice-sheet, and as it was shifted from its original position, there may have been some dragging of the substrata, leading to contortion and "terminal curvature."

The researches of Messrs. Chamberlin, Upham, and Crosby have shown how materials from the ground-moraine become "englacial"—being carried by overthrusts of ice to higher positions in its mass. In fact, much detritus is thus shifted along planes of slipping, when inequalities in the land cause higher portions of the ice to move obliquely upwards and over lower portions. Parts of the original stony base of the ice-sheet may here and there, however, have been left in the hollows of the irregular land-surface until the final melting of the ice. Had the icy agent overspread the Cotteswold region, the Rubble Drift before-mentioned would have largely contributed

[1] Proc. Cotteswold Club, vol. v, p. 43.

[2] Proc. Cotteswold Club, vol. vi, p. 150; see also H. B. W., "Jurassic Rocks of Britain," vol. iv, pp. 462–3.

[3] Quart. Journ. Geol. Soc., vol. xlviii, p. 314.

its materials to the Boulder-clay, as elsewhere such weathered rock has been removed, and incorporated into the Drift.

In parts of Norfolk where the bare Chalk comes to the surface, it now weathers into a kind of rubble, as may be seen near Wells; and, land-ice overspreading such a surface, the superficial layers would be frozen to its base, and, with the aid of a little Kimeridge Clay, the Chalky Boulder-clay would be readily formed. During the movement of the ice-sheet the lumps of chalk would become scored by pressure against tiny fragments of shattered flint and other hard rocks, along the shearing planes of the ice. As remarked by Crosby, the detritus reaching the highest levels in the ice is carried farthest, and we may infer that such was the case with so much débris of Chalk, the harder fragments of which have mostly suffered faceting and striation. This would occur along the many minor planes of movement in the ice which Chamberlin has so clearly pictured.[1]

Thus, on the melting back of the ice, the further travelled Chalk and flints became commingled with the more local débris; and when a subsequent movement of the ice took place, the ground-moraine was pressed into the tough material of which the Chalky Boulder-clay so generally consists, and this subjacent drift was itself disturbed in many places, and dislocated as if by faults.

It should be borne in mind that in certain areas, as in East Norfolk, an earlier Boulder-clay, the Cromer Till, no doubt furnished some erratics to the Chalky Boulder-clay which overspread it; while other travelled stones may have come from ice proceeding from western and north-western areas overriding the ice of the Eastern-Midland plain. Pebbles of quartz and quartzite may in part have been derived from Tertiary gravels, as remarked by Sir Henry Howorth.[2]

In his account of Ice-work in Edenside Mr. J. G. Goodchild long ago maintained that Boulder-clay was not dragged along between the ice-sheet and the rocks beneath, but that it was formed of the weathered detritus of the rocks and other loose material, and deposited on the melting of the ice at or not far from the areas where the Boulder-clay is now found. He also refers to the different currents of ice that may have been present over an area undergoing land-glaciation, and to which causes many admixtures of boulders from diverse localities may be due.[3] Other explanations of the "intercrossing of erratics" have been given by Mr. Clement Reid and Mr. Lamplugh, who point out that stones from various localities may have been scattered over the bed of the North Sea by floating-ice prior to the invasion of the area by land-ice, and many of these boulders would then become incorporated in the subsequent ground-moraine.[4]

[1] See "Recent Glacial Studies in Greenland": Bull. Geol. Soc. America, vol. vi, p. 199.

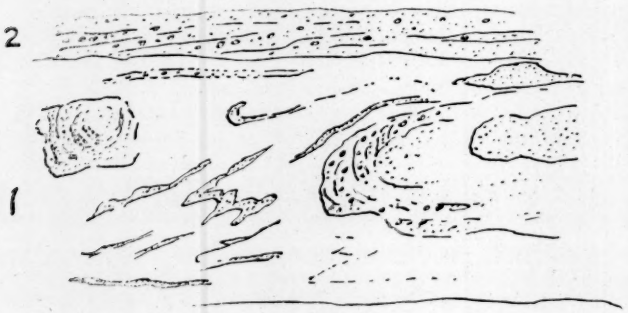
[2] Geol. Mag. 1896, pp. 455, 463.

[3] Quart. Journ. Geol. Soc., vol. xxxi, p. 55; and Trans. Cumberland Assoc., No. 11, 1887, p. 111.

[4] Reid, "Geology of Cromer," p. 90; Lamplugh, Geol. Mag. 1890, p. 67.

That the main features of the glaciated portions of the country were carved out very much as they are now before the accumulation of the Chalky Boulder-clay, is evident when we consider its distribution. It lies in patches, or great sheets, on the Oolitic uplands, from Stow Park, near Buckingham, to Lincolnshire, and on the Chalk plateaus from near St. Albans to Norfolk and the Lincoln wolds; it is found also in the vales beneath the escarpments, and near South Willingham, in Lincolnshire, it crosses the Cretaceous scarp. Its tendency, as a rule, has been to efface the old scenery, and the subsequent agents of denudation have only carved out minor valleys and separated the Boulder-clay into great sheets and numerous large and small outlying masses. The incorporation of so much Cretaceous and Jurassic material in the Boulder-clay, of course, means a great amount of erosion, but this, as a rule, took place from a scouring of the irregular land-surface, and was attended by a degradation rather than an intensification of the main features.

Fig. 1.—Pit by spinny, north-west of Thorpe Limekiln, Norwich.



2. Gravel and sand, 3 or 4 feet. Plateau Drift.
1. Stony loam with contorted seams and masses of sand and gravel, 16 feet. Contorted Drift.

When the agent which accumulated the Boulder-clay acted with greater power, the Chalk escarpment was considerably abraded, as in West Norfolk, and onwards to the neighbourhood of Stevenage and Hitchin. To the south-west we find no evidence of this planing down, the escarpment of the Dunstable and Luton Downs is bold, and so it is continued along the further range of Chiltern Hills. We do not find any Boulder-clay on the crests of these higher hills. Nevertheless, we find no Boulder-clay on the crests of the Lincolnshire Cliff, and this fact shows that we must be cautious in inferring an absence of glaciation where no relics at present exist. The presence, or absence, of loose and weathered rock, and other circumstances, must here aid our conclusions. Thus, in West Norfolk there is a marked absence of Clay-with-flints.

It is admitted that ice moving over ground-moraine cannot at the same locality erode.[1] Whether all the disturbances which we

[1] J. R. Dakyns, Geol. Mag. 1875, p. 169.

find in the upper layers of the subjacent strata were produced prior to the deposition of the Boulder-clay, may be open to question, but no doubt the majority were. S. V. Wood, jun., indeed, referred certain disturbances in the strata to a time when "this antecedent cushion of moraine" had been cut through by the ice.[1] He gave instances in the Oxford Clay near Huntingdon, in the Chalk near Litcham, and in the Contorted Drift near Norwich—the last instance being especially noteworthy when we bear in mind Wood's views regarding the Contorted Drift of the Cromer coast, the disturbances in which he attributed to grounding icebergs. The section Fig. 1, which I noted in 1876, is probably the one referred to by Wood.

Dealing now with the contorted underlying strata, we find evidence of their being generally disturbed by glacial action prior to the accumulation of the Boulder-clay. I have elsewhere figured disturbances in the Upper Lias Clay beneath Chalky Boulder-clay at Gayton Wharf, near Blisworth, in Northamptonshire;[2] and a disturbed surface of Great Oolite Clay and rubble beneath Boulder-clay at Maidford, north-west of Towcester.[3] In this latter case, as in another instance near Radstone, in Northamptonshire, it would seem that locally the severed soil and rubble had not been moved far—the stony base of the ice-sheet being perhaps arrested and over-ridden.

As before remarked, glaciated pavements in the Jurassic and newer formations of the Midland or Eastern Counties have but rarely been noted, nor could they often be produced in such easily disturbed strata. The most interesting example is that observed by Mr. W. J. Harrison in a cutting made in 1874–5 in widening the Midland Railway between Leicester and Wigston. Referring to the Boulder-clay, he remarks that "Its thickness here was between 20 and 30 feet. At the base the lower lias shales and limestones were exposed to a depth of 3 or 4 feet for a distance of about 400 yards. The limestones were most beautifully striated *in sitû*, the slightness of the dip having prevented the ripping up of the beds to any great extent, and the thick covering of clay having preserved them from the percolation of water. Oblong slabs of limestone, torn off, were to be seen lying in close proximity to the outcrop of each stratum, and a little to the south of it. In one spot the strata were bent up for a few yards into a sharp anticlinal curve."[4]

Where Boulder-clay rests on the New Red Sandstone in Icknield Street, Birmingham, it was observed by Crosskey that in places large fragments of sandstone had been disrupted and thrust into the middle of the Drift; elsewhere a part of the sandstone had "been lifted up almost like an arm," while the Drift had been accumulated beneath it.[5]

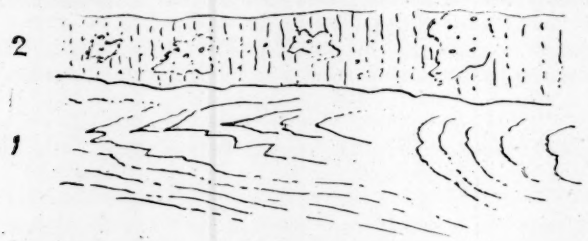
[1] See Quart. Journ. Geol. Soc., vol. xxxvi, pp. 482–90; and vol. xxxviii, p. 667.
[2] "Jurassic Rocks of Britain," vol. iii, p. 277.
[3] Ibid., vol. iv, p. 397; and Geol. Mag. 1897, p. 103.
[4] "A Sketch of the Geology of Leicestershire and Rutland," 1877, p. 45.
[5] Proc. Birmingham Phil. Soc., vol. iii, p. 213.

The Rev. J. M. Wilson noticed that at Bilton, near Rugby, the Lias Clay was contorted beneath glacial sand and gravel.[1] In that neighbourhood the Drifts lie very irregularly on the Lias, and there is evidence of sand and gravel above as well as below the Boulder-clay.

In 1870 Mr. C. J. Woodward drew attention to certain "Swilleys" or disturbed surfaces in the Lower Lias of Grafton and Binton, in Warwickshire. His illustrations depict these features as identical with others in the same district to which I have subsequently drawn attention—in ignorance at the time of his much earlier observations.[2]

At Church Honeybourne, east of Evesham, the Lower Lias Clay is contorted, and again at South Littleton the exposed beds of limestone and clay were nipped up on the surface in a series of sharp folds. As far west as Croome D'Abitot, near Pershore, in Worcestershire, similar evidences of surface-disturbance were observed.[3] Probably the "Lias clay with contorted beds of Lias limestone" noted in the railway-cutting at Dunhamstead by Strickland, in 1840, exhibited features of the same character.[4] At Halford, north of Shipston-on-Stour, I noticed that the beds of White Lias were much disturbed in places.

Fig. 2.—Section about one mile south of Surlingham St. Mary, near Norwich.



2. Brown stony loam (decalcified Boulder-clay) with unweathered remnants of Chalky Boulder-clay, 3 feet.
1. Blue clay and laminated clay and sand: contorted, 5 feet.

In this region, although the disturbances are similar to those produced by glacial action, we have (with the exception of the Aston Magna Drift) no distinct evidence of Boulder-clay, the superficial deposit being a few feet of reddish-brown clay with pebbles of quartz and quartzite. This is no doubt the deposit described by T. G. B. Lloyd as "light-red, sandy, unstratified clay, compact and hard, containing quartzose pebbles and a few boulders, which occasionally exhibit traces of glacial action." He observes that it is the "General Quartzose Drift" of Strickland and the "Northern

[1] Quart. Journ. Geol. Soc., vol. xxvi, pp. 194, 196; and Rep. Rugby Nat. Hist. Soc. for 1869, p. 30.

[2] Proc. Birmingham Nat. Hist. Soc. for 1870, p. 63. The labours of Mr. W. J. Harrison in preparing a bibliography of Midland Glaciology were thus appreciated. Mr. Harrison has since published a similar work for Norfolk.

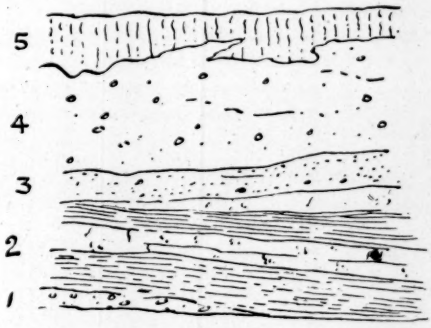
[3] H. B. W., "Jurassic Rocks of Britain," vol. iii, pp. 146, 150.

[4] Proc. Geol. Soc., vol. iii, p. 314.

Drift" of Murchison.[1] This Drift occurs here and there over a wide area in Warwickshire, and may be a result of the denudation of Boulder-clay.

During the progress of the Geological Survey in Norfolk and Suffolk, numerous instances of contortion in the strata underlying the Chalky Boulder-clay, and occasionally of intrusive tongues of that material, were noticed.[2] Chalk and Crag were in places disturbed, but the marked contortions were usually to be found where brickearth or clay, or thin alternating clays and sands, lay beneath the Boulder-clay. (See Fig. 2.) Where glacial muds. formed during temporary recession of the ice, were afterwards overridden, erosion without marked contortion was sometimes to be seen. (See Fig. 3.)

FIG. 3.—Pit one-quarter of a mile north-west of Dove Inn, Poringland, Norfolk.



5. Soil and decalcified Boulder-clay, 2 or 3 feet.
4. Chalky Boulder-clay.
3. Chalky sand (base of Boulder-clay). } 6 or 7 feet.
2. Yellowish laminated clays and bands of marl, 6 feet.
1. Chalky Boulder-clay.

Thick beds of yielding sand are, as a rule, but little, if at all, disturbed, as may be observed in the well-known coast at Kessingland, and again where the Boulder-clay rests on the remarkably false-bedded Lower Greensand at Grove Bury, near Leighton Buzzard. At the last-named locality, where the sections were noted by Mr. A. C. G. Cameron,[3] portions of the sand have been torn away and incorporated with the Boulder-clay, but the main mass of the Lower Greensand is wholly undisturbed. Sands which had been frozen to the base of the ice-sheet may have been so removed, but in their severance from the main mass of underlying sand no disturbance was therein produced.

Intruded masses of Chalky Boulder-clay have been noticed, not only beneath uptilted Chalk, but in the midst of soft gravels and

[1] Quart. Journ. Geol. Soc., vol. xxvi, pp. 205–6. See also paper on Gravels by H. J. Osborne White: Proc. Geol. Assoc., vol. xv, p. 157.

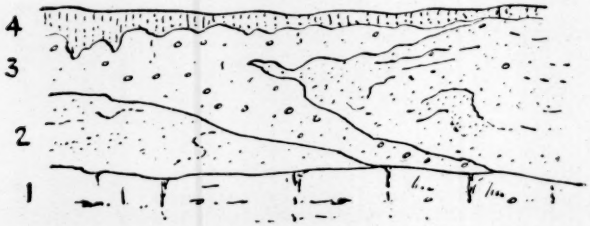
[2] "Geology of Stowmarket," by W. Whitaker and others, p. 9; "Geology of Bury St. Edmunds and Newmarket," by F. J. Bennett and J. H. Blake, p. 11; "Geology of Norwich," by H. B. Woodward, p. 112.

[3] See Ann. Report of Director-General of Geol. Survey for 1896, p. 79.

clays. Such examples I have seen at Surlingham, near Norwich, and at Claydon, near Ipswich, and Mr. J. E. Marr has figured strata at Sudbury that exhibit the same phenomena.[1] In some cases, perhaps, the basal portion of the ice carrying detritus was locally arrested, while higher portions of the ice moved onwards. The subsequent melting of this arrested ice led to an irregular accumulation of drift and contorted strata. In explaining the disturbed strata at Sudbury, Mr. Marr remarks that the basal portions of the land-ice would be compressed laterally when driven through valleys, and that contortion and even small faults might then be produced in the incorporated frozen strata. On the melting of the ice the Drifts would arrange themselves much as they are now found. Mr. Marr has also described fragments of Crag-sand which had probably been torn from the parent mass when in a frozen state, and redeposited without any disturbance of their bedding.

Mr. Whitaker, who examined the Claydon pit in 1875, then noted "a mass of Boulder Clay apparently intruded beneath older beds."[2] Portions of these older deposits were described by him as "much like the Crag," and with this view my notes made in 1890 quite agree. (See Fig. 4.)

Fig. 4.—Section at Chalk-pit, Claydon.



4. Soil and decalcified Boulder-clay.
3. Chalky Boulder-clay.
2. Sands and gravels (Crag series), disturbed.
1. Chalk.

Intrusive tongues, of course, can only be inferred where there is a manifest disturbance of the strata in connection with the Boulder-clay so introduced, or when the Drift has been thrust into a formation unquestionably of older date. The phenomena observed at Birmingham by Crosskey may here be considered. (See ante, p. 491.)

The larger masses or "cakes" of Secondary strata that have been incorporated in the Drift arouse peculiar interest. All of those found in the Eastern-Midland Counties may be connected with the agent which formed the Chalky Boulder-clay.

The great masses of disturbed Chalk, and the little broken sheets of the same rock with layers of flints, found in Norfolk, occur in the Contorted Drift. Mr. Clement Reid has, however, brought forward good evidence to show that the disturbances, and the introduction of

[1] Geol. Mag. 1887, p. 262, Fig. 1.
[2] "Geology of Stowmarket," pp. 9, 10.

the great Chalk boulders, belong to the period of the greatest glaciation, or of the Chalky Boulder-clay.[1] My own observations in Norfolk coincide, as the disturbed Chalk at Trowse was clearly connected with the Chalky Boulder-clay; so also were sundry remarkable disturbances in the Chalk near Wells.[2]

The long-disputed Boulder of Chalk at Roslyn Hole, Ely, is in direct association with the Chalky Boulder-clay; so also is the large tract of Chalk and rearranged Chalk discovered at Catworth by Mr. Cameron.[3] Again, the well-known masses of Lincolnshire Limestone that occur in the Drift at Great Ponton, as first observed by Professor Morris, are associated with the Chalky Boulder-clay, occurring in these and other cases at or near the base of the Drift.

A large transported mass of Marlstone, more than 200 yards across, was found by Professor Judd capping Beacon Hill, south of Swayfield. He remarks: "It is noteworthy that these masses always belong to the rocks which form the highest ground," and that "Some of the masses of the Marlstone Rock-bed have been carried across deep valleys, a distance of probably not less than 30 miles." He then attributed their transportation to floating-ice.[4]

More recently Mr. Fox-Strangways has observed "a mass of Lincolnshire Oolite, at least 300 yards long and 100 yards broad," to the north-west of Melton Mowbray,[5] and also a mass of Marlstone, 12 feet across, near Dunton Basset.[6] These also were included in the Chalky Boulder-clay.

Far west again, in the elevated region of the South Wales Coalfield, a transported mass of Carboniferous sandstone upwards of 200 yards in length has been discovered by Mr. W. Gibson. "Though its bedding is only slightly disturbed, yet the whole mass has been ascertained to lie upon Boulder-clay, and must therefore be regarded as a huge boulder."[7] It is interesting to note that Chalk-flints have been found in the Drift of this region; and, although we have no positive evidence to assert that it is of the same age as the Chalky Boulder-clay of the Midland and Eastern Counties, yet we may well believe that it belongs to the period of maximum glaciation.

Looking to the source of the larger cakes of Cretaceous and Jurassic rocks, we find that they occur in areas where the formations from which they were detached suffered marked denudation. As previously mentioned, the Chalk areas along the Fenland borders had been planed down, and it will be noticed that there is a singular absence of Jurassic outliers along the western margin of the great Lincolnshire "Cliff," and this absence may reasonably be attributed to their removal during the Glacial period.

[1] "Geology of Cromer," pp. 111–117.
[2] Quart. Journ. Geol. Soc., vol. xxxv, p. 106 (Proc.); "Geology of Norwich," p. 135; "Geology of Fakenham," etc., p. 22.
[3] Proc. Geol. Assoc., vol. xiii, p. 356.
[4] "Geology of Rutland," etc., pp. 246–7.
[5] Report of Director-General of Geol. Survey for 1892, p. 249.
[6] Geol. Mag. 1897, p. 57.
[7] Report of Director-General of Geol. Survey for 1894, p. 275.

Judging by facts, we may believe that these cakes and boulders were in some cases dislodged from outliers frozen to the base of the land-ice, and shifted to higher levels in the ice along planes produced by its movement over an irregular surface. Cliffs or escarpments, as well as outliers, locally formed impediments to the progress of ice.

As is well known, the Chalk in Norfolk, at Whitlingham, Trowse, and Trimingham, was markedly disturbed, and the evidence brought forward by Mr. Clement Reid and myself shows that great force must have been exerted, sufficient to bend the Trimingham Chalk into folds, and to uptilt the Trowse Chalk, whereby we see stages in the formation of the huge cakes of Chalk elsewhere disrupted and incorporated with the Drift. Cliffs that had been formed in the Chalk along Pliocene coast-lines may then have been effaced.

It is, of course, by no means improbable that some of the large masses of rock may have slipped from scarps on to ice when the ice-sheet was being temporarily melted back, and they may thereby have become incorporated into the subsequently thickened moving ice.[1]

At Hendon and Finchley masses of reconstructed London Clay have been incorporated in the gravelly Drifts, and these may have been torn from the parent strata during an early stage of the period of maximum glaciation.[2]

If we believe that the main mass of Boulder-clay was deposited on the melting back of the ice-sheet, or from the melting of basal portions of the ice, and that there were alternations in the climate so that the ice extended and receded for some distance more than once before it finally retreated, we can understand the intercalation of water-distributed sands and gravels, as well as laminated muds, with Boulder-clay, and more especially along the margin of the glaciated area. Such instances would, no doubt, follow the final retreat of the ice, and we have indeed examples at Wymondham, in Norfolk, of fine sand and coarse gravel interbedded with Chalky Boulder-clay. Instances are more frequent towards the southern area. Mr. Whitaker long ago drew attention to the intercalation of Boulder-clay in the sands and gravels of Hertfordshire, and there are fine examples at Tingewick, Radcliff, and elsewhere, near Buckingham, where coarse boulder-gravel with large blocks of Jurassic and other rocks, and finer gravel and sand, occur in association with the Boulder-clay.

The extensive tracts of gravel and loam on the Chalk areas of Buckinghamshire, in the vicinity of Chesham, Amersham, and Rickmansworth, may to some extent have resulted from the melting of ice, and the more or less torrential distribution of material, including large greywethers. Some beds of gravel were doubtless distributed during the earlier stages of the period of maximum glaciation, and they would yield an abundance of Jurassic

[1] See also T. M. Reade, Quart. Journ. Geol. Soc., vol. xxxviii, p. 232, and G. A. J. Cole, Geol. Mag. 1895, p. 553.

[2] See discussion on paper by Dr. Hicks, Quart. Journ. Geol. Soc., vol. xlvii, p. 583.

fossils such as we find in Drift gravels in Cambridgeshire, Huntingdonshire, and Hertfordshire. In many places Belemnites and Gryphæas are preserved when other fossils and fragments of limestone have been dissolved away. Some of these gravels have naturally been used up time after time, and probably only in the later of the gravels, except where protected by Boulder-clay, do we find many pebbles of Chalk or other kinds of limestone.

III.—On some Rock-Specimens from Kimberley, South Africa.

By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S.

(*Concluded from the October Number*, p. 453.)

2. *Dykes and other Igneous Rocks.*

ALTHOUGH not strictly in the order of the title, we may describe first a specimen from the so-called "melaphyre," which forms a great sheet high up in the group through which the diamond-bearing pipes have been driven. This, which bears the label "No. 5, Melaphyre," is nearly 5″ in length. Macroscopically, it may be described as a compact dark basalt, showing slight signs of decomposition, and containing rather sparse amygdales of irregular size and shape (the maximum length being about half an inch), filled mostly with calcite and spotted occasionally with dark-green. The specific gravity is 2·842. Microscopic examination shows the following constituents: (*a*) Plagioclase: microliths of this form a large part of the ground-mass, varying generally from about ·005 to ·007 in length, with a fair number nearly four times this size, but two or three, probably of earlier date, are from four- to six-tenths of an inch. Among these microliths are scattered granules and small grains of iron-oxide; also a filmy green mineral, exhibiting aggregate polarization, but whether it represents a pyroxene or a residual basic glass is not easily determined. Larger grains of augite indubitably have been present, which, however, are now replaced by acicular hornblende with parallel grouping. In addition to this, needles of this mineral, grouped in tufts, pierce, like pins, into the larger felspars. The latter are not in good preservation; they contain granules of iron-oxide and green specks. Vesicles from about one-twelfth of an inch downwards are found to be fairly numerous: they are now filled by a pale dull-green chlorite, which exhibits pleochroism from an ochre-yellow to a green, giving low polarization tints and apparently straight extinction. Now and then a grain or two of calcite or of epidote may also be present, especially in those of larger size, in which calcite dominates. Other enclosures occur: three wholly included, one, the largest (which cannot have exceeded a quarter of an inch in diameter), almost wholly; besides two others doubtful in nature because so little is left. Round each is a slightly interrupted zone of chlorite, usually not more than ·01″ broad, and sometimes a little calcite. They appear to be quartzite, but the structure is rather peculiar. The inner part consists of

grains of quartz, with the usual somewhat irregular outline. Certain of these, under crossed nicols, exhibit a slightly radial structure. This might be the result of strains in an exceptional direction, but it seems more likely to have been assumed during the formation of the grain. The outer part of the fragment, about one-eightieth of an inch wide, exhibits a chalcedonic structure, which seems to cut across the contiguous grains of quartz, and continues successively the dominant tint of each of these. I think this chalcedonic zone most probably the result of an external alteration of the original fragment and a phenomenon of contact metamorphism. There are a few enclosures and cavities in the quartz grains themselves, but these generally do not call for remark, except that one or two grains are crowded with very minute rounded spots of a light-brown material which appears to be anisotropic. I think these fragments come from the quartzite or quartz-grit, which is occasionally interbedded with the dark shales, and that they have been caught up by the "melaphyre." The latter perhaps is rather a diabase than a basalt, and is almost certainly a flow.

A specimen labelled "Basalt," without number or depth, looks as if it might be part of a rudely spheroidal mass; it appears to be a very fine-grained dolerite, and under the circumstances I have thought a microscopic examination needless.

"Igneous dyke No. 8, 1,200-feet level": is an irregular fragment of a dark-coloured, very fine-grained dolerite, its s.g. being 2·989. Microscopic examination shows that it consists mainly of four minerals: (*a*) Felspar, ill preserved, replaced by microliths, probably once plagioclase. (*b*) Augite, fairly idiomorphic, with characteristic cleavage, slightly brown in colour; showing at the exterior incipient replacement by a filmy green hornblende. (*c*) Prisms of a dull-greenish mineral enclosing flattish granules of opacite. This mineral (clearly secondary) occurs in parallel fibres or needles with slightly oblique extinction, and so probably is hornblende. The original mineral possibly might have been an enstatite, but I think some unstable form of augite is more probable. (*d*) Grains and occasional rods of iron-oxide sometimes passing externally into limonite. We also find small flakes of biotite; clear acicular microliths (? actinolite) piercing the felspars, and two or three grains, similarly pierced, of a water-clear mineral, like quartz, but probably a secondary felspar. Hence the rock is a rather altered dolerite, approaching a diabase.

"South of dyke No. 10, 1,200-feet level." This is a rather irregularly-shaped fragment, partly bounded by rude joint faces, a little more than six inches in length, of a dark, slightly speckled basaltic rock with a few irregular grains of pyrite. The slice exhibits the following minerals: (*a*) plagioclastic felspar, more or less replaced by secondary products; (*b*) brownish augite of dirty aspect, due to decomposition; (*c*) rather elongated prisms of a pale-green serpentinous mineral retaining indications of a platy cleavage, probably an altered enstatite; (*d*) iron-oxide in crystalline grains, sometimes also in rods or plates; (*e*) pyrite, occasionally forming an aggregate

of crystalline grains; (*f*) a few grains of calcite. The iron-oxide and the supposed enstatite appear to have crystallized first. I expect the crystallization of the augite and felspar was almost simultaneous. The augite and the enstatite are often closely associated, and sometimes two long prisms of the former enclose one of the latter, like a section of a sandwich. The rock may be called an enstatite diabase.

"Hard rock No. 18, 1,500-feet level": a dark basaltic rock, slightly speckled with grey, and with occasional grains of felspar. The specimen is about $5\frac{1}{4}'' \times 4'' \times 2''$. The minerals are practically identical with those in the last rock, but the augite is more often idiomorphic; rods of iron are more frequent, and these sometimes form rude gratings. Thus it also is an enstatite diabase. In the slice a small rock fragment, about one-eighth of an inch in diameter, is enclosed. This at first sight seems to have a base of a speckled pale-brown glass, but that, on applying the nicols, proves to be really holocrystalline. In it are scattered some greenish-brown rods and flakes, probably altered pyroxene or biotite, with a rosette of chlorite and a few granules of iron-oxide. I suspect this to have been an andesite, caught up by the more basic rock and altered by heat.

"Shaft rock No. 19, 1,540-feet level." This is a dark-coloured basalt, very minutely speckled with lighter-coloured felspar, and containing a few grains of pyrite. The fragment is roughly five-sided, about $3\frac{1}{2}$ inches across, and 1 inch at thickest. The s.g. is 3·033. Under the microscope the rock shows traces of a base of a pale-brownish colour, but this proves to be replaced by secondary microlithic products. In it the following minerals are thickly scattered: (*a*) plagioclase: a few moderate-sized, broken crystals, rather decomposed, are associated with grains of iron-oxide, and very many long lath-like clear crystallites, often in pairs, parted by a very thin wedge of the base; these are not seldom associated in rather divergent groups; (*b*) brownish augite, imperfectly idiomorphic, inclining to occur in clusters; (*c*) iron-oxide, in crystalline grains, granules, and rods, the second and third often associated to form knotty clubs, combs with sloping teeth, or (rarely) gratings. There are occasional grains of pyrite. The larger felspars certainly, the augite not improbably, represent an earlier stage in the history of the rock, which is a rather altered magma-basalt.

"Soft rock, 1,500-feet level, No. 17." This obviously differs much from all the others. It is an irregular fragment, not quite four inches long, of a rather light lilac-grey rock, mottled by dull-green spots, varying in shape and size. The s.g. is 2·667. The rock consists of a number of small lath-shaped felspars, with some rounded prisms and spots of a very pale-green mineral, which acts but feebly on polarized light, in a granular brownish-grey ground-mass, which appears to be crowded with tiny lath-like microliths and minute mineral specks. It breaks up, with crossed nicols, into irregular spots, with low polarization tints, like a devitrification structure. The above-named "dull-green spots" are filled-up cavities. The rock is now a variety of porphyrite.

3. *Sedimentary Rocks.*

"No. 7, Quartzite": a large angular fragment with subconchoidal fracture, of a darkish quartzite or hard grit, somewhat felspathic, bearing a general resemblance to that described on the last occasion.[1] It seemed needless to have this sliced.

"No. 9, north of dyke, 1,200-feet level."[2] A squarish block (about $4'' \times 3'' \times 2''$) bounded by joint faces of a darkish-grey, fine-grained felspathic sandstone. Under the microscope we see subangular to rather angular quartz grains, seemingly set in a matrix of minute sericite-like flakes. This also suggests in places the former existence of grains, which occasionally show the remains of felspar. Some dark irregular spots (yellowish-white with reflected light) prove with a magnification of about 80 diameters (which this rock requires) to be aggregates of more or less translucent yellowish to brownish granules, perhaps hydrocarbons. There are a few small, rather rounded zircons, with other less important microliths. The quartz grains appear to have been slightly enlarged. I have no doubt the rock was once a quartz-felspar grit, but it has been somewhat altered, perhaps by heated water.

"North-east side of dyke, 1,200-feet level": a large fragment, smoothed on one side, of a fairly hard mudstone, in colour greenish-grey, somewhat banded with darker layers (not sliced).

"No. 4, Black Shale." This rock effervesces rather briskly with HCl, and is a dark, compact or minutely granular, non-laminated, calcareous mudstone, traversed by some very small veins of pyrite, possibly with slight traces of gold. In the hope of finding remains of organisms I had a slice prepared. The rock consists of roundish or subangular granules of variable size, speckled brown, separated by dark lines probably of carbonaceous matter. A few flakes of a mica, probably a bleached biotite, are also present. I cannot recognize any organisms, but one or two of the smaller grains exhibit a ring-like structure, recalling the form of certain spores. The grains generally show whitish to pinkish tints with crossed nicols, and I think are very probably a dolomitic calcite, mixed with earthy and carbonaceous matter. One or two small veins apparently are filled with the first mineral.

"No. 2, Limestone": a compact cream-coloured limestone. As the depth is not stated, I have not had it sliced, but I think it more likely to have been formed by precipitation than by true sedimentation, and to be from one of the tufaceous deposits said to occur in the upper part of the diamantiferous breccia.

"No. 6, Agate": a mass of chalcedony and quartz which has been formed in a cavity of a compact, rather decomposed basalt, or possibly basic andesite.

"Calcite": from a vein of calcite with abundant pyrite and possibly traces of copper, which apparently has traversed a darkish, rather hard shale.

[1] Geological Magazine, 1895, p. 500.

[2] The 2 in 1,200 is damaged, and may be a higher figure.

4. *Conclusion.*

I believe, as I have already stated,[1] that the diamonds were not produced where they are now discovered, but, like the conspicuous olivine, pyroxenes, mica, garnets, and iron-oxides, had their origin at a much greater depth in the earth's crust. Thus I think it improbable that the carbon was obtained from the Karoo Shales. In other words, I consider the diamonds, whatever may have been their past history, to have come from the crystalline floor[2] on which these shales were deposited, or to be at any rate Pre-Triassic in age. I see no reason why carbon should not be present in the earth's magma, whether it afterwards crystallized in a peridotite or in native iron.[3]

Volcanic action probably began before the end of the Karoo epoch, as the great sheet of so-called melaphyre seems to be intercalated with its higher deposits,[4] and some of the dykes may be approximately coeval with it. Afterwards (was it because of this impenetrable cover of lava?) the pipes were formed, probably in a short time, by a series of great explosions, caused by gases accumulated at considerable depth. These sent the outer part of the crystalline floor, including the diamonds, as well as the overlying Karoo shales, flying shattered into the air. Cones and craters may have been built up above these pipes, but I expect that, like some of those in the Eifel, they were never high, and that the shattered material mostly fell back, after a few explosions, into the pipes and filled them like the "necks" in Scotland. Then the volcano, after some more lava had struggled to reach the surface (forming, at any rate, the dykes in the necks), passed into a solfatara stage, during which the numerous secondary changes mentioned above were produced, the carbonates were deposited, and the minor structure of the mass was obscured. Afterwards ordinary meteoric agencies began to work; water percolating from above still further affected the mass, more especially in its upper parts, producing the "yellow ground" and the "soft blue" and depositing tufa.

The result of this examination is to confirm me in my opinion that the diamantiferous rock—the so-called Kimberlite—is a volcanic breccia rather than a peculiar form of peridotite. While it is difficult, owing to secondary changes, to demonstrate the fragmental character of the matrix, I have failed to identify it with any form of peridotite (or serpentine) known to me, and I cannot understand

[1] Geol. Mag. 1895, p. 501.

[2] It must be remembered that pyroxenite, troktolite, and gabbro are frequently found associated with peridotites and are generally intrusive in them.

[3] That graphite, cliftonite, carbonado, and diamond occur in the native iron, is, of course, well known: see Fletcher, Min. Mag., vii, 121. Meteorites vary from almost pure native iron to peridotites: see Wadsworth, "Lithological Studies," ch. ii, and Crookes, *Nature*, lvi, p. 325. Native iron is well known to occur in some basalts.

[4] According to Sir W. Crookes, F.R.S., "The Diamond Mines of Kimberley" (Lecture at Imperial Institute), the section is as follows: (1) soil, (2) basalt, much decomposed, 20′–90′, (3) black shale (combustible), 200′–250′, (4) "melaphyre," about 400′, (5) quartzite, about 400,′ (6) variable shales.

how masses of that rock, the smallest of which is about 370 yards in diameter,[1] masses, of which one has been traced to a depth of 500 yards, could remain throughout in a practically uniform glassy condition.

P.S. — This paper was written before the publication of the notice of the late Professor Lewis' work (p. 366). On a few points, as will have been seen, I differ from its author, but need only refer to the following. Two are inaccuracies: on p. 367, line 6, for "original" read "unpublished," and line 13 for "three" read "two." There was no manuscript of Section III, unless a few references could be thus called. A third is an error (p. 368): the largest inclusion in plate i is said to consist of rather decomposed compact serpentinized olivines and pyroxenes. This reads to me rather like nonsense, and I do not make the statement. I assert the fragment to be "a rather decomposed compact serpentinous rock." I now believe it is identical with some of the fragments described above. In regard to the "Hard Wack Floating Reef," which the writer apprehends may be the "Kimberlite proper," and laments that "no detailed examination" of this rock has been given, I need only remark that the slices used by Professor Lewis all represented the same *species* of rock, the difference among them being only varietal (none had descriptive labels); also that I strongly suspect I have examined a specimen of it, furnished to me by the late Professor A. H. Green (under a different name), and believe it to be nothing else than a more compact variety of the ordinary rock. I fail to understand the reviewer's remark about local writers and the shale on p. 368. So far as I remember, Professor Lewis nowhere asserts that the shale fragments are fused at the edges. A fragment of shale may be *altered* yet not *fused*. The perofskite I am disposed to consider generally, if not always, a secondary mineral.

IV.—Notes on the Geology of County Waterford.

1. The Fauna of the Ordovician Beds near Tramore.

By F. R. Cowper Reed, M.A., F.G.S.

Introductory.

DURING an examination of the complicated series of Lower Palæozoic rocks in County Waterford, with which I am still engaged, I have had the opportunity of collecting largely from the few fossiliferous beds in the neighbourhood of Tramore, and a study of the fossils throws considerable light on the vexed question of their age. It is not my intention in this paper to discuss the relations of the igneous and sedimentary rocks, nor to attempt to explain the structure of the district. The palæontological evidence of the exact horizon of certain fossiliferous beds will here alone be

[1] The largest must be about 450 yards in diameter. Some of the necks in Scotland are considerably larger than this. See Sir A. Geikie's "Ancient Volcanoes of Great Britain," chs. xxv and xxxi.

considered, with a view to establish a definite base-line which has previously been wanting in descriptions of these rocks. The confusing statement has frequently been made that a mixture of Llandeilo and Bala fossils is found in these beds and elsewhere in Ireland, and that the principles of classification followed in Great Britain are not applicable. From my study of the literature on the Lower Palæozoic of this part of Ireland, and from my investigations in the field and museums, I feel convinced that this startling opinion is due partly to the erroneous identification of the fossils, partly to confusing fossils from distinct horizons, partly to the repetition by folds, etc., of the same beds, and partly from misapprehension of the distribution or vertical range of some species. I have given below a list of the literature containing references to the fossiliferous and associated rocks of this district, but for the above reasons we cannot unfortunately rely on the lists of fossils which are said to occur in them, and I have consequently drawn my conclusions only from specimens collected in the various localities by myself or from those of identifiable horizons which I have personally examined.

1821. Thomas Weaver, "On the Geological Relations of the East of Ireland": Trans. Geol. Soc., ser. I, vol. v, p. 117.

1824. Rev. R. H. Ryland, "The History, Topography, and Antiquities of the County and City of Waterford." 8vo. London (*passim*).

1833. J. Hodgson Holdsworth, "On the Geology of the District of the Knockmahon Mines": Journ. Geol. Soc. Dublin, vol. i, p. 85.

1839. Sir R. Griffith, "On the Principle of Colouring adopted for the Geological Map of Ireland, etc.": Journ. Geol. Soc. Dublin, vol. ii, pt. 1, p. 78.

1839. Major Austin, "A brief Notice of the Geology around the Shores of Waterford Haven": Proc. Geol. Soc., vol. iii, p. 154.

1840. Th. Weaver, "On the Geological Relations of the South of Ireland": Trans. Geol. Soc., ser. II, vol. v, p. 1.

1841. T. Austin, "Observations relative to the Elevation of Land on the Shores of Waterford Haven, etc.": Proc. Geol. Soc., vol. iii, p. 360.

1841. J. Apjohn, Presidential Address: Journ. Geol. Soc. Dublin, vol. ii, p. 132.

1843. General J. E. Portlock, Geol. Rep. Londonderry, pp. 262, 283, 292, etc.

1844. Sir R. Griffith, "On certain Silurian Districts of Ireland": Rep. Brit. Assoc. Trans., p. 46.

1844. H. N. Nevins, "Some Remarks on Three Localities of Silurian Fossils lately discovered in Co. Waterford": Journ. Geol. Soc. Dublin, vol. iii, p. 78.

1844. "Localities of Silurian Fossils lately discovered in Waterford, Wexford, and Wicklow": Journ. Geol. Soc. Dublin, vol. iii, part 1, p. 57.

1845. Sir R. Griffith, "On the Order of Succession of the Strata of the South of Ireland": Journ. Geol. Soc. Dublin, vol. iii, p. 150.
1846. F. McCoy, "Synopsis of the Silurian Fossils of Ireland," pp. 7, 16, 26, etc.
1852. J. Beete Jukes, "Sketch of the Geology of the County of Waterford": Journ. Geol. Soc. Dublin, vol. v, p. 147.
1854. Sir R. Murchison, "Siluria," 1st ed., p. 166.
1856. J. Kelly, "Researches among the Palæozoic Rocks of Ireland": Journ. Geol. Soc. Dublin, vol. vii, p. 115.
1857. Sir R. Griffith, "Notes on the Stratigraphical Relations of the Rocks of the South of Ireland": Journ. Geol. Soc. Dublin, vol. viii, p. 7.
1859. J. Beete Jukes and Professor Haughton, "The Lower Palæozoic Rocks of the South-East of Ireland": Trans. Royal Irish Acad., vol. xxiii, p. 563.
1860. J. Kelly, "On the Graywacke Rocks of Ireland as compared with those of England": Journ. Geol. Soc. Dublin, vol. viii, pp. 2, 251.
1860. W. B. Brownrigg and Theo. Cooke, "Geological Description of the District extending from Dungarvan to Annestown, Co. Waterford": Journ. Geol. Soc. Dublin, vol. ix, p. 8.
1865. Memoir Geol. Surv. Ireland, Explan. Sheets 167, 168, etc.
1869. W. H. Baily, "Notes on Graptolites and Allied Fossils occurring in Ireland": Quart. Journ. Geol. Soc., vol. xxv, p. 158.
1872. Sir R. Murchison, "Siluria," 5th ed., p. 173 et seq.
1878. G. H. Kinahan, "The Geology of Ireland," p. 27.
1878. Prof. Hull, "Physical Geology and Geography of Ireland," p. 13.
1879. Prof. Ch. Lapworth, "Distribution of the Rhabdophora": Ann. Mag. Nat. Hist., ser. v, vol. iv, p. 424.
1891. Prof. Hull, "Physical Geology and Geography of Ireland," 2nd ed., p. 16.
1895. A. McHenry and W. W. Watts, "Guide to the Collection of Rocks and Fossils belonging to the Geological Survey of Ireland," pp. 82, 89, 90.
1897. Sir A. Geikie, "Ancient Volcanoes of Great Britain," vol. i, pp. 242–50.

Description of the Beds and their Fossil Contents.

The best preserved and most abundant fossils near Tramore occur in three principal sets of exposures, but the beds represented in those localities are by no means all on the same horizon.

1. Taking the localities in order from east to west, we begin with the most easterly ones in the townlands of Quillia and Castletown. On the one-inch Geological Survey Map, Sheet 179, there is marked in about a mile east of the Tramore-Waterford Railway a sinuous band of limestone. The rock consists of a greyish calcareous sandstone, weathering to a brownish-yellow colour, and containing a large

number of fossils. The exposure in the field south of the Castle in the townland of Castleton (locality 17 of the Survey Memoir, Explan. Sheets 167, 168, etc.) is in an old overgrown quarry in which the dip of the beds is still visible, and is marked on the map as 80° N.W. From this small exposure I obtained, with difficulty, the following fossils:—

Phacops Jamesi, Portl.
Orthis flabellulum, Sow.
O. crispa, McCoy
Phyllopora Hisingeri, McCoy
Stenopora fibrosa, Goldf.
S. (?) *lycoperdon*, Hall

All of these also occur in the far richer locality at Quillia, to be immediately mentioned, and in addition to the above there are recorded in the Survey Memoir the following species:—

Cheirurus bimucronatus, Murch.
Cybele verrucosa, Dalm.
Illœnus Bowmani, Salt.
Orthis calligramma, Dalm.
Orthis elegantula, Dalm.
Plectambonites (*Leptæna*) *sericea*, Sow.
Rafinesquina expansa, Sow. (*Strophomena concentrica*)

The species of *Phacops* recorded in the Survey Memoir here and at Quillia as *Ph. Brongniarti* is really *Ph. Jamesi*, as I have determined by examination of the Survey specimens. I have not myself found nor recognized in any collection specimens of the true *Ph. Brongniarti* from these places.

At Quillia, about a mile south of the Castletown locality, this brown calcareous sandstone is exposed in the banks of a lane leading to a farm off the high road; it dips to the NNW. at about 50°. Its fauna is rich in individuals, but not particularly so in species. The following fossils I have collected at this spot:—

Asaphus gigas, De Kay
Cybele tramorensis, Reed
C. verrucosa, Dalm.
Phacops Jamesi, Portl.
Orthis calligramma, Dalm.
O. crispa, McCoy
O. elegantula, Dalm.
O. testudinaria, Dalm.
Rafinesquina expansa, Sow.
R. deltoidea, Conr.
Plectambonites sericea, Sow.
Caryocystites granatum, Forbes
Echinosphærites, sp. (?)
Glyptocrinus, sp. (?)
Stenopora fibrosa, Goldf.
Nebulipora lens, McCoy (?)

Of the above fossils *Phacops Jamesi* is by far the most abundant. *Plectambonites sericea* is also very plentiful. In the Dublin Museum there is from this spot a head-shield of *Cybele tramorensis*, a species which I described[1] from a solitary specimen found here by me in 1894. The Survey Memoir also mentions the following species from Quillia:—

Amphion pseudo-articulatus, Portl.
Calymene brevicapitata, Portl.
Orthoceras Brongniarti (?), Troost

The next locality for fossils lies on the west side of the Tramore-Waterford Railway, and the exposures occur on the hill in the townland of Pickardstown. It is sometimes spoken of as Drumcannon and corresponds to "locality 19" of the Survey Memoir.

There is more than one fossiliferous bed exposed on this hill, and the relations of the various beds are fairly plain. On the lower slopes of the east side of the hill occur black slates dipping N.W.

[1] Geol. Mag., Dec. IV, Vol. II, 1895, p. 49, Pl. III, Fig. 1.

at about 50°; in these no fossils have as yet been found. They resemble in general character the great mass of highly folded unfossiliferous slates between this locality and Quillia. Above these slates comes a crushed calcareous flaggy sandstone (*a*) full of *Rafinesquina expansa*. In the quarry near Hammondville at the south end of the ridge the intrusive diabase is seen to be in contact with a greyish limestone, which is split up at this spot by thin shaly bands (*b*) containing very abundant Entomostraca. Thick bedded limestone (*c*) is found well exposed in a large quarry towards the north end of the ridge, and is the source of the majority of the fossils. It is a very tough bluish-grey rock when freshly broken, but weathers into a rotten brownish material. Perfect specimens are difficult to extract from it. It dips into the hill at about 45° N.W. and overlies the above-mentioned beds. Above it is a bedded felsite, which also can be traced sweeping round the northern end of the hill. In a lane at the north-west corner of the hill a sandy fossiliferous limestone is found dipping SSE. at about 60°, and containing *Orthis crispa*, *Rafinesquina expansa*, and *Stenopora fibrosa*. Thus we seem to have a synclinal existing in the hill. The diabase exposed in the southern quarry is found to cut obliquely across all the beds and is traceable to the northern end of the hill. The following fossils were collected by me from these beds:—

(a) *Phacops Jamesi*, Portl.
Orthis calligramma, Dalm., var.
Rafinesquina expansa, Sow.
Stenopora fibrosa, Goldf.

(b) *Agnostus agnostiformis*, McCoy
Encrinurus sexcostatus, Salt.
Harpes, sp.
Trinucleus concentricus, Eaton (?)
Primitia mundula, Jones
P. mundula var. *longa*, Jones
P. mundula var. *producta* (?), Jones[1]
Turrilepas, sp. (?)

(c) *Amphion pseudo-articulatus*, Portl.
Lichas, sp.
Phacops Jamesi, Portl.
Orthis calligramma, Dalm.
O. crispa, McCoy
Pleetambonites sericea, Sow.
Plectambonites quinquecostata, McCoy
Conularia, sp.
Glyptocrinus, sp. (?)
Stenopora fibrosa, Goldf.
Nebulipora lens, McCoy (?)

In the Survey Memoir and Collection there are the following additional fossils from this locality:—

Asaphus gigas, De Kay
Cheirurus gelasinosus, Portl.
Cybele verrucosa, Dalm.
Rafinesquina deltoidea, Conr.
Palæaster obtusus, Forbes

It will be seen on comparison of the lists that the fauna is practically identical with that from Quillia. The slight difference in the fauna of the shaly beds here is to be attributed to the different character of the deposit and of the original physical conditions. The abundance of *Phacops Jamesi* is a noteworthy feature at both Quillia and Pickardstown.

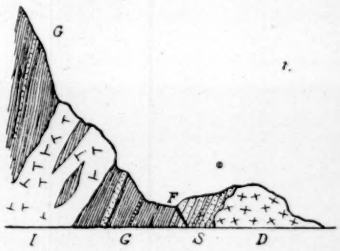
2. South of Tramore there is exposed along the coast a series of fossiliferous beds belonging to different horizons in the Ordovician system. The lower beds consist of black or dark-grey calcareous slates, which dip at high angles below bedded sandy limestones

[1] Professor Rupert Jones has kindly examined and named the specimens of Entomostraca from these beds.

containing nodular layers largely composed of *Stenopora* (?) *lycoperdon*. The black slates are exposed on the foreshore, and mostly only at low-water, between Tramore and Lady Elizabeth's Cove. The limestones form generally the base or whole face of the cliffs in the intervals between the igneous rocks. Where the sequence of beds is distinct, the black slates are found to become calcareous in their upper portion and to pass into thin-bedded shaly limestones, which are succeeded by the arenaceous nodular limestones, as may be seen near Lady Elizabeth's Cove. North of Lady Doneraile's Cove, however, and towards Tramore, the relations of these beds are much confused by faulting, folding, and intrusions of igneous rocks, and a fault-breccia frequently occurs along the line of their junction.

Fossils have not been found in the main mass of these slates; but in the small cove nearly opposite Carrigaghalia and adjoining on the north that cove called the "Ladies' bathing-place," there are seen in the cliffs black soft fissile argillaceous slates, dipping at 80° WNW., which in the Ladies' Cove are much pierced by igneous intrusions and contain graptolites (Fig. 1). Unfortunately their relation to

Fig. 1.—Section in Cove opposite Carrigaghalia.



G. Graptolitic black shales, with thin flags and calcareous bands.
S. Flags.
D. Intrusive diabase.
I. Intrusive andesitic dolerite, enclosing patches of G.
F. Fault.

the arenaceous limestones of the cliffs north of Lady Elizabeth's Cove is not here seen, but in lithological characters they may be compared with the much crushed black slates between Lady Doneraile's Cove and Tramore, in which, however, no fossils have yet been found. These underlie the arenaceous limestones; and for palæontological reasons, as will appear, we must consider the graptolitic slates of the Ladies' Bathing Cove also to belong to a stratigraphical horizon immediately below the arenaceous limestones.

The following graptolites were collected by me in the black slates of the Ladies' Bathing Cove[1]:—

Climacograptus perexcavatus, Lapw.
Cryptograptus, sp.
Dicellograptus sextans, Hall (?)
Dicranograptus Nicholsoni, Hopk.
D. ramosus, Hall

[1] Miss G. Elles, of Newnham College, kindly identified these for me.

A spicule of a Lyssakine Hexactinellid sponge, kindly identified by Dr. Hinde, F.R.S., was also found by me in these beds.

All these graptolites occur in the Glenkiln Shales of Scotland; and in addition to the above there are in the Dublin Museum the following, labelled "Lady Elizabeth's Cove, Tramore," but contained in exactly identical black slates and probably from the same spot as my specimens. Mr. Clark, of the Geological Survey of Ireland, has kindly furnished me with the list of the species, and the specimens I have also examined myself:—

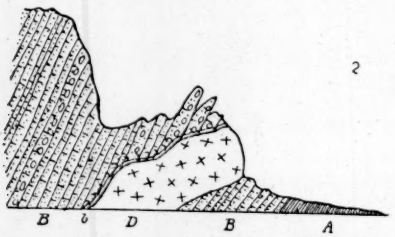
Climacograptus bicornis, Hall
Cœnograptus gracilis, Hall
Didymograptus, sp.
Dicellograptus, sp.
Dendrograptus, sp. (?)

In addition to the above, Professor Lapworth[1] quotes the following list of graptolites given by Baily,[2] from "dark shales in Tramore Bay":—

Climacograptus bicornis, Hall
Cœnograptus gracilis, Hall
Dicellograptus sextans, Hall
Dicranograptus ramosus, Hall
Didymograptus, sp.
Diplograptus foliaceus, Murch.

The whole assemblage is characteristic of the Glenkiln Shales, and we can therefore have no hesitation in ascribing the black slates which I have mentioned to that horizon. The list of graptolites given in the Survey Memoir of this district from the same locality (designated "locality 21") is misleading, owing to the incorrect determination of the species. No Ordovician beds older than these graptolitic shales have so far been proved to exist in this district.

Fig. 2.—Section in Cliffs, West Side of Tramore Bay.



A. Black calcareous slates on foreshore.
B. Sandy impure and nodular limestones.
D. Intrusive diabase.
b. Crushed beds at junction.

The next beds to be described are the impure limestones which immediately overlie the graptolitic beds. These arenaceous and nodular limestones, which are so prominently developed along the coast from Tramore to Newtown Cove, contain in bands here and there a large number of fossils, which are, however, difficult to extract in anything but a fragmentary condition. The beds dip at angles from 45° to 70° to the WNW., but the average angle is

[1] Lapworth, Ann. Mag. Nat. Hist., ser. 5, vol. iv, 1879, p. 424.
[2] Baily, Q.J.G.S., vol. xxv, 1869, p. 158.

about 60°. (Fig. 2.) I have collected the following fossils from them :—

Calymene Blumenbachi, Brong.
C. brevicapitata, Portl.
Cybele, sp.
Phacops Jamesi, Portl.
Orthis calligramma, Dalm.
Plectambonites sericea, Sow.
Rafinesquina deltoidea, Conr.
Stenopora fibrosa, Goldf.
S. (?) *lycoperdon*, Hall

In the Survey Memoir it appears that the fossils from "locality 20" come principally from the sandy limestones; but a slight uncertainty prevails on this point, since on p. 19 of the Memoir the beds are described as "grey calcareous slates," while on p. 28 they are called "compact bluish limestones" and "brown shaly beds." The Newtown Cove fossils are also included in the description, but they come from beds which are stratigraphically rather higher and have a somewhat different faunistic facies, though a few species are common to them and the sandy limestones. The following fossils in the Survey and other collections seem to come from these sandy limestones :—

Ampyx mammillatus, Sars.
Asaphus gigas, De Kay
Calymene brevicapitata, Portl.
Cybele verrucosa, Dalm.
Encrinurus sexcostatus, Salt.
Illænus Bowmani, Salt. (?)
Lichas, sp.
Phacops Jamesi, Portl.
P. truncato-caudatus, Portl.
Remopleurides Colbii, Portl. (?)
Trinucleus seticornis, His., var. (?)
Phyllopora Hisingeri, McCoy
Ptilodictya dichotoma, Portl.
Porambonites intercedens, Pand.
Plectambonites sericea, Sow.
Orthis biforata, Schloth.
O. crispa, McCoy
O. elegantula, Dalm.
Rafinesquina deltoidea, Conr.
R. expansa, Sow.
Cyrtoceras (?) *inæquiseptum*, Portl.
Conularia, sp.
Glyptocrinus, sp.

If the foregoing lists are compared with those of the fossils from Pickardstown and Quillia, no important differences are apparent, except in the relative abundance of some forms such as *Phacops Jamesi*, which is rare near Tramore, while extraordinarily abundant at the other localities. This might be due to the less calcareous character of the Tramore beds rather than to any difference in the age of the strata, but the occurrence of the forms *Ampyx mammillatus* and *Remopleurides Colbii* may indicate a slightly higher horizon, since these genera are so prevalent in the overlying Newtown Cove beds, and are absent at Pickardstown, etc. Moreover, since the Tramore beds pass up into the Newtown Cove beds, whereas at Pickardstown a felsite immediately overlies the fossiliferous beds, it is probable that the latter correspond only with the lower part of the coastal series. Black slates underlie the calcareous fossiliferous beds in both localities, and there is no reason to doubt that they are of the same age, though palæontological evidence is, so far, unfortunately wanting. The correspondence in the faunas of the Tramore, Pickardstown, and Quillia rocks is so great that it seems impossible to do otherwise than group them together in the same *assise*; the dissimilarity in the bionomic conditions which is indicated by the difference in the lithological character of the

rocks and succession at each locality, appears sufficient to account for the slight modification in the relative abundance of some species and for the appearance of some new forms. The Newtown Cove beds have a somewhat different fauna, and must be considered separately.

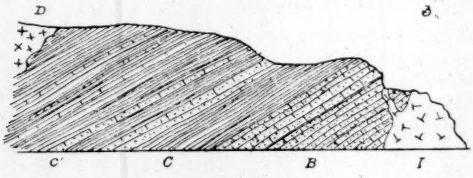
The correlation of these impure limestones is not difficult when we remember that they immediately succeed beds containing a Glenkiln fauna. If we look at the succession in the South of Scotland, we see the Balcletchie beds with a somewhat similar fauna containing Hartfell graptolites, and the Hartfell Shales immediately succeeding the Glenkiln Shales. Additional evidence is afforded by the fact that some fossils of the Tramore limestones are only known in Great Britain from the Balcletchie and associated beds (*Asaphus gigas, Cheirurus gelasinosus, Porambonites intercedens*), while one species (*Asaphus gigas*) is absolutely peculiar to the Balcletchie beds.

Certain species of the Tramore limestones are, however, peculiar, and have not so far been found outside Ireland :—

Amphion pseudo-articulatus.
Cybele tramorensis.
Phacops Jamesi.
Phacops truncato-caudatus.
Palæaster obtusus.

This may be partly due to the fact that Ireland belonged to a different but adjoining zoological province, and partly that the Tramore limestones are not exactly on the same horizon as the Balcletchie

Fig. 3.—Section at Newtown Cove.



B. Sandy impure limestones.
C. Dark calcareous shales with fossils.
C'. Greenish calcareous shales and mudstones with thin limestone bands, weathering yellowish-brown.
D. Intrusive diabase.
I. Intrusive andesitic dolerite.

beds. The latter suggestion is rendered all the more probable from the much closer correspondence of the fauna of the overlying Newtown Cove beds with that of the Balcletchie beds. I would therefore consider the Tramore limestones as corresponding with only the lower portion of the Balcletchie beds of Scotland, and with the whole or some portion of the underlying Benan conglomerate.

3. These Newtown Cove beds are found immediately above the impure limestones of the cliffs, and are well seen in the sides of the

glen leading down to Newtown Cove, near the Metal Man, Tramore (Fig. 3). The lowest beds there exposed consist of blackish calcareous slates weathering a dark rusty-brown, and they are overlain by pale grey and greenish soft calcareous shales and mudstones with thin impure limestones, which decay into a very soft yellowish or pale-brown rock. The uppermost beds are dark argillaceous slates. The beds dip at 40° W., and in the section exposed in the road-cutting in Newtown Cove, they are succeeded by an andesitic dolerite, apparently intrusive. Fossils are very abundant in these beds, and I have myself collected the following species :—

(*a*) Lower beds (*C*, dark calcareous shales).

Calymene brevicapitata, Portl.
Calymene, sp.
Cheirurus, n.sp.
Cybele verrucosa, Dalm.
Harpes Dorani, Portl.
H. Flanagani, Portl.
Phacops Brongniarti, Portl.
P. Jamesi, Portl. (?)
Remopleurides dorsospinifer, Portl.
R. platyceps, McCoy
Trinucleus concentricus, Eaton (?)
Primitia mundula var. *producta*, Jones
Orbiculoidea, sp.
Orthis crispa, McCoy
Plectambonites quinquecostata, McCoy
P. sericea, Sow.
Echinosphærites arachnoideus, Forbes (?)

These beds, in which trilobites are by far the most abundant fossils, both in species and individuals, pass up imperceptibly into the still more fossiliferous overlying calcareous shales and mudstones. The latter contain the following species, all of which I have personally collected :—

(*b*) Upper beds (*C'*, calcareous mudstones, etc.).

Agnostus agnostiformis, McCoy
Ampyx mammillatus, Sars.
A. cf. *nasutus*, Dalm. (? = *A. rostratus*, Sars.)
Asaphus gigas, De Kay.
A. laticostatus, McCoy (?)
A. rectifrons, Portl.
Barrandia Portlocki, Salt.
Barrandia, sp.
Calymene Blumenbachi, Brong.
,, ,, var.
Cheirurus gelasinosus, Portl.
Cheirurus, sp.
Cybele verrucosa, Dalm.
Cyphoniscus, n.sp.
Encrinurus sexcostatus, Salt., var.
Harpes Dorani, Portl.
Harpes, sp.
Illænus Bowmani, Salt.
Lichas hibernicus, Portl. (?)
Phacops Brongniarti, Portl.
P. truncato-caudatus, Portl.
Remopleurides Colbii, Portl.
R. dorsospinifer, Portl.
R. laterispinifer, Portl.
R. platyceps, McCoy
Trinucleus concentricus, Eaton (?)
T. hibernicus, Reed
Primitia, sp.
Turrilepas cf. *scotica*, Nich. and Eth.
Orthis calligramma, Dalm.
O. crispa, McCoy
O. elegantula, Dalm., var. *parva*
Plectambonites quinquecostata, McCoy
P. sericea, Sow.
Helminthochiton Griffithi, Salt.
Glyptocystites cf. *Logani*, Billings
Crinoid stems.

This is a remarkable assemblage of fossils and is specially comparable with that in the Balcletchie Shales. The trilobites also in beds (*a*) and (*b*) are very similar to those found in the Ordovician beds at Tirnaskea, in Tyrone,[1] in which the following Newtown Cove fossils are said to occur :—

[1] Mem. Geol. Surv. Ireland, Sheet 34 (1878), p. 25.

Ampyx rostratus, Sars.
Asaphus gigas.
Calymene brevicapitata.
Cybele verrucosa.
Harpes Dorani.
Illænus Bowmani.
Lichas hibernicus.
Remopleurides Colbii.
Trinucleus concentricus.
Orthis calligramma.
Plectambonites sericea.

The prominent feature of the fauna at Tirnaskea, as at Newtown Cove, is the trilobites, but the almost complete absence of mollusca at the latter place is a striking difference.

It is the Balcletchie fauna which bears the closest resemblance. Messrs. Nicholson and Etheridge[1] record the following Newtown Cove species from the Balcletchie beds :—

Agnostus agnostiformis.
Asaphus gigas.
Cheirurus gelasinosus.
Cybele verrucosa.
Illænus Bowmani.
Lichas hibernicus.
Phacops Brongniarti.
Remopleurides laterispinifer.
Turrilepas scotica.

Several species of *Ampyx* are also recorded.

Professor Lapworth[2] mentions the following species from the Balcletchie beds, all of which occur at Newtown Cove :—

Asaphus gigas.
Phacops Brongniarti.
Remopleurides dorsospinifer.
Orthis calligramma.
Plectambonites quinquecostata.
P. sericea.

The genus *Barrandia*, which seems confined to the Lower Bala, is also mentioned. Of special importance do I consider the occurrence of the restricted species *Asaphus gigas* and *Cheirurus gelasinosus*. The former species is only found in America in the homotaxial Hudson River beds and the Trenton Limestone. *Glyptocystites Logani*[3] is also a Trenton Limestone species. The occurrence of some peculiar species (*Harpes Dorani, H. Flanagani, Barrandia Portlocki, Remopleurides platyceps, Trinucleus hibernicus*) gives the fauna the usual special Irish stamp.

The presence of typical Lower Bala species and genera, and the very close affinity of the fauna to that of the Balcletchie beds, demonstrate unmistakably the horizon of the Newtown Cove beds; and the palæontological evidence is found to be confirmed by the stratigraphical as shown in the field.

The succession, therefore, of the fossiliferous beds near Tramore is as follows :—

(4) Shales, mudstones, and impure limestones of Newtown Cove (= greater portion of the Balcletchie Beds).
(3) Impure sandy limestones of Tramore Bay cliffs, including towards the base the Quillia and Pickardstown beds (= lower portion of the Balcletchie Beds and portion of the Benan Conglomerate).
(2) Black slates of Carrigaghalia, etc. (= Glenkiln Shales).
(1) Unfossiliferous dark slates.

The fauna and succession of the beds at Newtown Head, near Passage, will be described on a subsequent occasion, as well as the other fossiliferous Ordovician beds in County Waterford.

[1] Mon. Girv. Silur. Foss., 1879, pp. 228–9.
[2] Q.J.G.S., vol. xxxviii, 1882, p. 586.
[3] Billings, Canad. Organ. Rem., 1858, dec. iii, p. 57, pl. iv, fig. 1.

NOTICES OF MEMOIRS.

ABSTRACTS OF PAPERS READ BEFORE SECTION C (GEOLOGY), BRITISH ASSOCIATION, TORONTO, 1897.

I.—PRELIMINARY NOTICE OF SOME EXPERIMENTS ON THE FLOW OF ROCKS.—By FRANK D. ADAMS and JOHN T. NICHOLSON, McGill University, Montreal.

THESE experiments aim at ascertaining whether it is possible, by subjecting rocks artificially to pressure under the conditions which obtain in the deeper parts of the earth's crust, to produce in them the deformation and cataclastic structures exhibited by the folded rocks of the interior of mountain ranges or of the older formations of the earth.

Three factors contribute toward bringing about the conditions to which rocks are subjected in the deeper parts of the earth's crust: (1) great pressure from every direction; (2) high temperatures; (3) action of percolating waters. In the present experiments the attempt has been made to reproduce only the first of these conditions; in subsequent experiments the endeavour will be made to reproduce all three of them.

The experiments have been made chiefly with pure Carrara marble. Columns of the marble, 2 centimetres and $2\frac{1}{2}$ centimetres in diameter and about 4 centimetres in length, were very accurately turned and polished. Heavy wrought-iron tubes were then made, imitating the plan adopted in the construction of ordnance, by rolling long strips of Swedish iron around a bar of soft wrought iron, and welding the strips to the bar as they were rolled around it. The core of soft iron composing the bar was then drilled out, leaving a tube of welded Swedish iron 6 millimetres thick, so constructed that the fibres of the iron run around the tube, instead of being parallel to its length. This tube was then very accurately fitted on to the column of marble. This was accomplished by giving a very slight taper to both the column and the interior of the tube, and so arranging it that the marble would pass only about half-way into the tube when cold. The tube was then expanded by heating, so as to allow the marble to pass completely into it, and leave about 3 centimetres of the tube free at either end. On allowing the tube to cool, a perfect contact between the iron and marble was obtained, and it was no longer possible to withdraw the latter. Any very slight failure to fit at any point, if such a failure existed in any case, was rendered harmless by the fact that under a comparatively low pressure the limestone is found to be sufficiently elastic, not only to fill up any such minute space, but even to stretch the tube, and, on the pressure being relieved, to contract again to its original form, so that it will drop out of the tube which has been thus enlarged. Into either end of the tube containing the small column an accurately fitting sliding steel plug was inserted, and by means of these the marble was submitted to a pressure far above that which would be sufficient to crush it if not so inclosed. The machine employed in obtaining the pressure

was so arranged that the pressure might be maintained for weeks, or even months, if required. Under these circumstances, the conditions of pressure to which the marble is subjected are those in the "zone of flow" of the earth's crust—those, namely, of a pressure above that of its elastic limit, while yet unable to break in the ordinary manner, owing to the tube which confines it having a still higher elastic limit. Under the pressure, which was applied gradually and in some cases continued for several weeks, the tube was found to slowly bulge until a very marked enlargement of the portion surrounding the marble had taken place. The tube was then cut through longitudinally by means of a milling machine along two lines opposite one another.

The marble within, however, was still firm, and held the respective sides of the iron tube, now completely separated, so tightly together that it was impossible without mechanical aids to tear these apart. By means of a wedge, however, they could be separated, splitting the marble through longitudinally. The column in one experiment was reduced from 40 millimetres to 21 millimetres in height. The deformed marble differs from the original rock in having a dead white colour, the glistening cleavage faces of calcite being no longer visible, and although not so hard as the original rock, it is still firm and compact, and especially so when its deformation has been carried out very slowly. No accurate measurements as to its strength have yet been made, but it will withstand a sharp blow, and fragments of it, weighing 10 grams, have been allowed to fall through a height of over $2\frac{1}{2}$ metres (8 feet) on to a wooden platform, from which it rebounded without breaking. Thin sections of the deformed marble, when examined under the microscope, show that the calcite individuals composing the rock have in many cases been twisted and flattened, and in the majority of cases a very fine polysynthetic pressure-twinning has been induced in them, with movement along gliding planes, as well as several other structures seen in nature in highly deformed rocks.

The experiments therefore show that limestone, even when dry and at ordinary temperatures, does possess a certain degree of plasticity, and can be made to "flow," the movements set up developing many structures which are characteristic of rocks which have been squeezed or folded in the deeper portions of our earth's crust.

II.—The Glaciation of North-Central Canada. By J. B. Tyrrell.

In the region immediately west of Hudson Bay the earliest glaciation of which any traces were recognized, flowed outwards from a gathering-ground which lay north or north-west of Doobaunt Lake. Subsequently this gathering-ground moved south-eastward, until it centred over the country between Doobaunt and Yath-kyed Lakes. From one or other of these centres the ice seems, to the writer, to have flowed westward and south-westward to within a short distance of the base of the Rocky Mountains; southward, for more than 1,600 miles to the States of Iowa and Illinois; eastward into the basin of Hudson Bay; and northward into the Arctic Ocean.

No evidence was discovered of any great elevation of this central area in Glacial or immediately Pre-Glacial times, and, in the absence of such evidence, it would seem not improbable that the land then stood at about the same height above the sea as it stands at present. In this case, the moisture giving rise to the immense precipitation of snow would have been derived from the adjacent waters of Hudson Bay and the Arctic Ocean.

The name Keewatin glacier has been applied to this central continental ice-sheet. In general character it appears to have been somewhat similar to the great glacier of North-Western Europe, with a centre lying near the sea-coast, a steep and short slope seaward, and a very much longer and more gentle slope towards the interior of the continent. But there was this difference between the two, that the centre of the latter was over a high rocky country, from which the ice naturally flowed outwards towards the surrounding lower country; while the centre of the former was over what is now, and was probably also then, a low-lying plain, on which the snow accumulated to such depths as to cause it to flow over country very considerably higher.

After the Keewatin glacier had reached its full extent, it began gradually to decrease in size. As it disappeared from the Northern States and the North-West Territories of Canada, it left a series of moraines, many of which can be readily traced across the unwooded country as ridges of rounded stony hills. While retiring down gradually descending slopes, many temporary extra-glacial lakes were formed in front of it, and were drained one after another as it retired to still lower country. Before it had withdrawn from the Winnipeg basin, it was joined by an advancing glacier from the east, and, in front of the two, Lake Agassiz, one of the largest of the extra-glacial lakes, was formed.

In its final stages the general gathering-ground of the Keewatin glacier seems to have moved still farther eastward, or nearer to the coast of Hudson Bay, and to have broken into several separate centres, one of which lay over the country south-east of Yath-kyed Lake, while another was probably located north of the head of Chesterfield Inlet.

After the retirement of the Keewatin glacier the land in the vicinity of Hudson Bay stood from 500 to 600 feet below its present level, and gradually rose to its present height.

III. — Glacial and Interglacial Deposits at Toronto. By Professor A. P. Coleman, Ph.D., Toronto University.

THE ravines of the river Don at Toronto and the lake cliffs of Scarborough Heights, a few miles to the east, provide exceedingly interesting sections of the drift, from 100 to 350 feet in thickness, displaying three or more sheets of till and a varying number of interglacial beds.

The most important section, at Taylor's brickyard in the Don Valley, shows a lowest till overlying Cambro-Silurian shale of Hudson River age. Upon this rest 18 feet of sand and clay, containing many unios and other shells, as well as leaves and pieces

of wood. Some of the unios do not now live in Canadian waters, but are found in the Mississippi; and several species of trees now belonging to the States to the south occur with them, indicating a climate decidedly warmer than the present. Above this come stratified clay and sand, with a caribou horn and remains of insects and plants belonging to a colder climate than the present. This set of clays and sands is best shown at Scarborough, where the series rises 148 feet above Lake Ontario, and contains many species of extinct beetles, as well as shells of mollusca, mosses, and wood of hardy trees.

A complicated middle till overlies these beds, which were deeply eroded before the advance of the ice. Another less important fossil-bearing interglacial bed occurs above the middle till at elevations up to 240 feet above the lake, and is followed by a third till. Great changes in the level of the water occurred in connection with these climatic changes, the lake being much lower than at present before the first glacial advance and after the first interglacial time. During the deposition of the middle till, and also while the last sheet of till was being deposited, the water stood from 250 to 300 feet above the present level of the lake, which stands 247 feet above the sea. The retreat of the last ice-sheet was followed by the Iroquois episode, leaving a well-marked elevated beach. The length of time required for the first interglacial period is probably to be estimated at thousands of years; and during this time, at the beginning of which the climate was very warm, the ice-sheet of the Laurentide glacier must have completely disappeared. The correlation of the series of events described with those of the drift of the United States and of Europe is difficult, but probably the chief interglacial period corresponds to Jas. Geikie's Neudeckian, or the interval between the Iowan and Wisconsin glacial advances.

IV.—On the Structure and Origin of certain Rocks of the Laurentian System. By Frank D. Adams, Ph.D., F.R.S.C., McGill University, Montreal.

THE paper presents the results of recent and somewhat extended studies of several areas of the Laurentian of Canada, and deals more particularly with the origin of certain members of this system as indicated by their structure or composition. While it is impossible in the present state of our knowledge to arrive at any definite conclusions concerning the origin of many, or perhaps even of the majority, of the rocks composing the Laurentian, the origin of certain members of the system can be determined. Some of these, although now possessing a more or less distinct and even highly pronounced foliation or stratiform appearance, can be proved to be igneous or intrusive rocks, while it can be shown that others are of aqueous origin.

To the former class belong the anorthosites and many of the orthoclase gneisses. These rocks, although frequently distinctly foliated, can in many places be traced into perfectly massive varieties, and form great intrusions, interrupting and cutting off the older

members of the system. The foliation and stratiform appearance, which led the older geologists to class them as altered sediments, is due to movements induced by pressure, and they show protoclastic or cataclastic structure in great perfection.

To the aqueous rocks, on the other hand, belong the crystalline limestones and certain gneisses usually associated with them. These rocks not only differ in structure from those above referred to, but have a chemical composition not possessed by any igneous rock. The cataclastic structures are very subordinate, and the rocks are characterized by a very extensive recrystallization, accompanied by the development of new minerals.

It may therefore be said, without going beyond that which the facts warrant, that there are in the Laurentian at least two distinct sets of foliated rocks. One of these, comprising the limestones, some quartzites, and certain garnetiferous or sillimanite gneisses, represents, in all probability, highly altered and extremely ancient sediments. The other set, intimately associated with these, is of igneous origin, and comprises numerous and very extensive intrusions, both acid and basic in character, which were probably injected at widely separated times. Those masses which were first intruded, and have been subjected to all the subsequent squeezing and metamorphism, are now represented by well-defined and apparently interstratified augen-gneisses and granulites; others, intruded at later periods, though showing the effects of pressure, retain more or less of their massive character; while still others, which have been injected since all movements ceased, are recognized by all as undoubted igneous intrusions.

REVIEWS.

I.—International Geological Congress.—Congrès Géologique International. Compte-Rendu de la Sixième Session, en Suisse. 8vo; pp. xii, 710, with Supplement (Table of Strata). Lausanne, April, 1897.

THE Sixth Session of the International Geological Congress was held at Zurich in 1894, and just before the Seventh Session was held at St. Petersburg, nearly three years after date, the volume of 1894 proceedings was issued. Like the previous volumes published by the Congress, the present work contains a miscellaneous series of discussions, reports, and original papers on various geological subjects, together with records of excursions. Most of the articles are in French, but some are in German, and others in English; and among the subjects dealt with are Ontogeny and Phyllogeny, the structure of gneisses and gabbro, New Zealand glaciers, the geology of Arabia and Palestine, Alpine geology. Contact metamorphism, and Quaternary and Tertiary classification.

Perhaps the most important article is that by Professor Renevier entitled "Chronographe Géologique," being an explanatory statement to accompany a second edition of his "Tableau des Terrains Sedimentaires," which originally appeared in 1873–4 in the *Bulletin de la Société vaudoise des sciences naturelles*, vol. xii, and

is now issued as a supplement to the volume before us. This Table is printed on coloured papers, the colours for each geological system corresponding with those adopted on the Geological Map of Europe in course of publication by the Congress. The Table is an elaborate and comprehensive one. In it are indicated the prominent biological zones in each stage, and also the various types of deposit, organic and detrital, and the conditions under which they were accumulated, from the Abyssal to the Aerial, in the principal localities where they have been recognized. The author has received help from many geologists, especially from Karpinsky in reference to Carboniferous, from Kayser in reference to Devonian, and from Lapworth with regard to Silurian. The Table is not put forward as the authoritative scheme of the Congress; it is essentially an independent work; but the author's hope is, that it will serve as a basis for an international Table of Formations constructed essentially on chronological grounds. In his explanatory remarks he gives much information on the history and usages of various terms, and adds a "Repertoire Stratigraphique" or glossary of terms applied to different divisions of strata in various parts of the globe. On these matters he invites criticism and correction, and without doubt he will have no reason to complain that they are wanting.

In treating of the geology of the globe where peat and blown sand have been formed in one area while radiolarian ooze was being slowly accumulated in another, we certainly require other terms than those of Norwich Crag, Kimeridge Clay, or May Hill Sandstone. The general biological and physical history of the globe must in the main be an indoor study to the individuals who attempt to deal with so vast a subject, for they must gather the materials from the detailed observations of the many local workers. The question is, how far can the local workers adopt the general terms now proposed, and at the same time make known the results of their labours in terms that would be locally applicable and intelligible. Formations are restricted to certain areas, and their time-limits vary not only in different countries but within varying geographical limits in one region. Without local names, of course, the stratigraphy of a district can never be clearly explained. Were the terms adopted by Renevier to come into use, the Middle and part of our Lower Lias would be *Pliensbachian*, our New Red Marl would be *Juvavian*, the Spilsby Sandstone would be *Berriasian*, the Atherfield Clay *Barremian*, the Bracklesham Beds *Lutetian*, and the Coralline Crag *Plaisancian*. In some cases our formations would fairly correspond with the time-limits implied by the general terms; in other cases our formations would represent but a portion of an age, or belong to more than one age. Such difficulties in the way of general correlation are well understood and recognized by all geologists; and if a universal scheme be adopted, then the local formations of each country can perhaps be referred to as Tremadoc Beds (Potsdamian), Magnesian Limestone (Thuringian), or Inferior Oolite (Bajocian), without implying more than an approximate correlation. It must be borne in mind that serious differences exist

with regard to the time-limits that should be indicated by some of the terms such as Bajocian. Even in the volume before us we find instances of divergent views. Mr. Warren Upham would, and we think rightly, employ the term Quaternary for Pleistocene, and Holocene or Recent. Renevier places Quaternary as a synonym of Pleistocene. Moreover, the classification of Tertiary strata proposed by Sacco (p. 230) differs in several important particulars from that given by Renevier.

We would protest against the use of such vague terms as Pre-Pliocene, Supra-Lias, and Infra-Lias for epochs or series; even such names as Malm and Dogger for Jurassic divisions are objectionable in a universal table of strata, for both terms in this country are locally applied in very different senses. It is not in accordance with custom and decidedly awkward to place the Lias in the Jurassic series and yet to put it below *Jurassique Inférieur*! Mr. Jukes-Browne may have something to say in regard to the grouping of Albian, Vraconian, and Rotomagian in the Middle Cretaceous or Cenomanian. That there is plenty of room for criticism in this Table of Strata, will be admitted; and certainly all will not agree with the placing of Arvonian as a subdivision of Laurentian, and with the assignment to it of the "problematic organism" *Eozoon Canadense*!

Despite these objections, we feel grateful to Professor Renevier for the great labour he has bestowed on a most important though vexatious subject, and for thus preparing the way for some settled and more definite chronological nomenclature. H. B. W.

II.—Geological Survey of Canada. Geological and Topographical Map of the Northern Part of the Lake of the Woods and Adjacent Country. Scale, two miles to one inch. (April, 1897.)

THIS region was geologically surveyed by A. C. Lawson; see Report CC, Annual Reports, New Series, vol. i, 1885; A. P. Coleman has furnished information on some points. The map has been compiled and drawn by A. E. Barlow (1885) and W. J. Wilson (1897). The sources of information are given in a marginal note.

Three parallel geological NW.–SE. sections are given, on approximately the same scale as the map, traversing the country north and south of the Lake, two near its western and one at its eastern end. The Index for the Formations refers to:—I. Huronian (Keewatin), comprising (1) Hydromicaceous and nacreous schists, with some associated chloritic and micaceous schists, and including areas of altered quartz-porphyry. (2) Clay-slate, mica-schist, and quartzite, with some fine-grained gneiss. (3) Agglomerates and other coarse clastic rocks, all more or less schistose, and generally of volcanic origin. (4) Hornblende-schists and altered traps, with some chlorite-schists, of volcanic origin. II. Laurentian. (5) Coarse-grained gneiss. III. Irruptive. (6) Later irruptive basic rocks. (7) Felsite, micro-granite, quartz-porphyry. (8) Granite.

Ten marginal notes afford particulars about these formations, and on other local points. The first two groups of schists, slate, gneiss, etc., are more or less *auriferous*, with many promising veins.

III.—Geological Survey of Canada, 1897. Geological Map of part of the Trail Creek, Mining Division, West Kootenay District, British Columbia. Scale, one mile to one inch. Geologically surveyed by R. G. McConnell. Preliminary edition.

THE Map, with contours, was compiled and drawn by J. McEvoy, from original surveys and plans of railways and the Department of Lands and Works, British Columbia. The series of rock-formations indicated on the map are:—(1) Conglomerate (Tertiary?). (2) Palæozoic volcanic rocks, effusive and fragmental. (3) Altered basic igneous rocks (serpentine, etc.). (4) Gabbro. (5) Schists and granite-gneisses (Shuswap series?). (6) Younger granite. (7) Older granite.

Each of these rock-groups has a marginal note descriptive of characteristics, area, etc. Notes "8" and "9" refer more particularly to the *auriferous* rocks, thus:—

Note 8. "The sulphide ores of the district are associated principally with the basic igneous rocks, and especially with the central gabbro area, around which the principal mines, so far worked, are grouped. The veins have an approximately east-and-west strike, and, with few exceptions, dip to the north at high angles. They follow lines of fissuring; and, so far as present evidence goes, belong to the class known as 'replacement veins.' The lodes are somewhat irregular, and vary in size from small stringers and disseminated grains to great ore-bodies, forty feet or more in width. The principal ores are pyrrhotite and chalcopyrite, often associated with pyrite and mispickel and occasionally with molybdenite. Cobaltiferous mispickel, or danaite, occurs at the 'Evening Star,' and gersdorffite, a sulph-arsenide of nickel, at the same mine, and at the 'Columbia-Kootenay.' Besides the above minerals, galena and blende occur in some of the mines situated near the outskirts of the main mineral area. The ores are often more or less siliceous, and calcspar is occasionally met with in seams and pockets; but, as a rule, the principal gangue is the ordinary country-rock of the district, usually only slightly altered. The gold contents of the ores are exceedingly variable, ranging from traces up to several ounces per ton. The smelter-returns of 1,200 tons of 'Le Roi' first-class ore are given by Mr. Carlyle as 2·6 oz. of gold, 1·8 oz. of silver, and 2·5 per cent. of copper; and of 4,800 tons second-class ore as 1·34 oz. of gold, 1·4 oz. of silver, and 1·6 per cent. copper."

Note 9. "Fissure veins filled with a quartz gangue are occasionally met with in this district. The best known of these is the 'O.K.' mine, situated west of Sheep Creek, but a number of locations have also been made on Murphy Creek, Grouse Mountain, and other places. The veins vary in size from a few inches to six feet or more, and carry free gold and auriferous sulphides of iron, copper, and lead."

The index to the numbers of the mining claims comprises 240, 457, 459, 531, and on to 1,692, with some exceptions.

IV.—Geological Survey of Canada. G. M. Dawson, C.M.G., LL.D., F.R.S., Director. Annual Report (New Series), vol. viii, Reports A, D, J, L, R, S, for 1895. With numerous plates and maps. 8vo. (Ottawa: Dawson, 1897.)

THE Summary Report (A, 154 pages) of the Geological Survey Department, by the Director, treats of the progress and work done in explorations and surveys, and in the museum, library, and office generally, during 1895.

In Report D (117 pages, with a map and three plates), J. B. Tyrrell and D. B. Dowling describe the country between Athabasca Lake and Churchill River, treating of the Laurentian, Huronian, Cambrian, Cretaceous, and Pleistocene rocks, with the physical geography of the region, especially along the several routes.

Report J (184 pages, with two maps and eleven plates, besides nine smaller figures), by Frank D. Adams, is a very interesting résumé of what is known of the geology and economic resources of that portion of the Laurentian region lying north of the Island of Montreal. The earlier observations by Logan and others are carefully recorded, and the co-operation of colleagues is fully acknowledged. The following general statement (p. 10), regarding the Archæan rocks here treated of, is important:—

"That portion of the area occupied by the Archæan is underlain for the most part by a series of gneisses, presenting great variations in both structure and composition, and with which are associated crystalline limestones, quartzites, etc. These belong to the 'Grenville Series' of Sir William Logan,[1] and are of Laurentian age. In certain parts of the area, however, there are great stretches of orthoclase-gneiss, much more uniform in character, and without limestones and quartzites. These are referable, in some cases at least, to the 'Fundamental Gneiss' of Logan, which was by him believed to underlie the Grenville Series, and to form the basal member of the Laurentian system.

"Breaking through these gneisses, and in some cases interbanded or interstratified with them, are several anorthosite masses, by far the largest of these being that which for purposes of convenience may be termed the 'Morin anorthosite,' and which comprises an area of 990 square miles. Two important intrusions of acid rocks, one of granite and the other of syenite, also occur in the district.

"In the present Report the anorthosites are shown to be intrusions, and are separated from the Laurentian proper. The name 'Laurentian' is therefore made to embrace the Fundamental Gneiss, which, although, so far as can be ascertained at present, essentially igneous in origin, may possibly contain sedimentary material, and the Grenville Series, which is composed of altered sediments, associated with much injected igneous matter."

I.—The Laurentian gneisses and their associated rocks are described stratigraphically and petrographically (pp. 11, etc.). The Grenville Series of banded, foliated, and faulted gneisses, and the associated

[1] "Geology of Canada," 1863, p. 839.

crystalline limestone, quartzite, garnet-rock, intrusive syenite, and apparently deep-seated granite, are described in detail. The gneisses are divisible into (1) those of igneous origin (pp. 38, etc.); (2) those of sedimentary origin (pp. 49, etc.) with limestones and quartzites; and (3) some gneisses of doubtful origin (pp. 67, etc.).

II.—Of the Anorthosite groups, that of the Morin area is first described (pp. 85, etc.), as to its stratigraphy and petrology. It varies in its constituents and structure, the latter frequently showing the results of pressure and movement. At page 115 we read :—

"It would thus seem that the clastic structure described as occurring in these anorthosites occupies, in a way, a position intermediate between the 'protoclastic structure' of Brögger and the cataclastic structure commonly observed in sheared rocks.

"In the Morin area, then, we have a great intrusive mass of anorthosite, or gabbro very rich in plagioclase, breaking through the Laurentian, cutting off successive horizons, including portions of the gneiss, sending an apophysis into it, and in some places bounded by a zone of rock which exhibits many characteristics of a contact-product. This mass in most places shows irregularities in size of grain, and in some places a streaked or irregularly banded structure, while in one part of the above-mentioned apophysis it is well foliated, which foliated structure there is reason to believe is a secondary one. It certainly does not represent a partially obliterated bedding, as the earlier observers seem to have believed, while the other supposed evidences of the existence of a great overlying sedimentary series, of which it was supposed to form part, are also wanting; the gneiss and limestone with which it was thought to be interstratified really belonging to the Grenville Series, while the apparent interstratification of the anorthosite is due to intrusion.

"The whole is furthermore unconformably overlain by flat unaltered strata of Potsdam and Calciferous age, and thus possessed in Cambrian times the characters which it now presents; while the nature of the anorthosite, and its relation to the Laurentian, lead us to suppose that it is much nearer in age to the latter than to the overlying Cambro-Silurian, probably not much more recent than the Grenville Series itself."

Other anorthosite masses, in seven distinct areas, are then described (pp. 116, etc.), accompanied by a table of analyses of various plagioclasic or anorthositic rocks, together with notes of the occurrence of such rocks in Norway, Russia, Egypt, and the United States. Post-Archæan dykes are described at pp. 134, etc. This Report also comprises valuable notes (pp. 139, etc.) on the economic materials of the region, including iron-ores, graphite, apatite, mica, "infusorial" (!)—probably diatomaceous—earth (used locally for whitewashing buildings), garnet-rock,[1] limestone, marble, and anorthosite (some used for paving-stone).

Report L, by A. P. Low (387 pages, including seven appendices, with four plates and four maps), is on explorations in the Labrador

[1] The hybrid and therefore very improper word "garnetiferous" is used throughout this Report, wherever "garnet-bearing" could and should have been used.

Peninsula along the East Main, Koksoak, Hamilton, Manicuagan, and portions of other rivers, in 1892–5. Mention is made of the sources of information about the history, physical geography, and natural history of the region explored; acknowledgment is made of kind help and hospitality given by officers of the Hudson Bay Company; and the work of colleagues and assistants is carefully recorded. The elaborate chronological account of previous discoveries and explorations (pp. 7–19) is of great interest; it extends from 990 to 1891. The physical geography, climate, soil, trees and other plants, the population, and fisheries, are successively dealt with. Detailed descriptions of the routes explored follow (pp. 56–195). The observations by Mr. Low and the Assistant Surveyors on the geological structure of the great territory under notice were made along widely separated lines of exploration, but afford the means of making an approximate estimate of the distribution and extent of the areas of the different rocks, their mutual relationship, modes of occurrence, and relative age; also of their economic materials, and of the features and conditions of surface due to glacial action (pp. 195–311).

"The term 'Laurentian' is employed to designate the complex mass of highly crystalline Archæan rocks of which the greater part of the Labrador Peninsula is composed. These do not differ in any essential particulars from those similarly designated in other parts of Canada. They consist chiefly of gneisses and schists, some of which are believed to be highly metamorphosed materials of clastic origin, while others are regarded as foliated eruptives. As it is not possible, except in limited areas, to separate these rocks on the map, they are necessarily treated together. . . . . Under the name 'Huronian' are included several widely separated areas of clastic and volcanic rocks, together with many basic eruptives; these are represented by various schists, conglomerates, breccias, diorites, and other rocks more or less interfolded with the Laurentian.

"The Cambrian rocks rest unconformably upon the Laurentian and Huronian, and are made up of bedded sandstones, argillites, shales, and limestones, along with bedded traps and other basic intrusive and volcanic rocks. . . . .

"The Laurentian and Huronian gneisses and schists are intensely folded. This folding took place long previous to the deposition of the sedimentary beds of Cambrian age; and a sufficiently long time had elapsed between the period of folding and the Cambrian submergence to allow for great removals of material by denudation, and for the main sculpturing of the Peninsula. . . . . The enormous lapse of time requisite for the formation of the Hamilton inlet and river-valley can hardly be conceived if the denudation was not much greater than that under present conditions."

We may note that "the anorthosite is a variety of gabbro, made up of labradorite, holding isolated masses of hypersthene or rhombic pyroxene, ilmenite, and mica. In texture it varies from exceedingly coarse, with crystalline faces sometimes nine by six inches, to a fine-grained saccharoidal form. The colour is generally a shade of violet,

and is mostly dark, especially in the coarser varieties, which sometimes have a green tinge. The fine-grained variety is always light-coloured, varying from white to light shades of pink and violet. Along the north shore of Michikamau Lake, where the rock is very coarse-grained, many of the crystal faces show a beautiful iridescent play of colour, in shades of green, blue, and bronze-yellow" (p. 230). This *precious labradorite* is again mentioned at page 289.

Appendix I, by A. P. Low, consists of a scientific list of the Mammalia of Labrador; Appendix II, of the birds; III, of the principal food fishes; IV, of the Insects, by Dr. James Fletcher. Appendix V contains Mr. W. Ferrier's notes on the microscopic structure of thirty-four rocks from Labrador; Appendix VI is an elaborate tabular and classified catalogue by J. M. Macoun of the known plants of Labrador; Appendix VII is D. V. Eaton's Meteorological Observations in the Peninsula in 1893–5.

Report R, by Dr. G. Ch. Hoffman and his Assistants, F. G. Wait and R. A. A. Johnston, exhibits such portion of the work carried out in the Laboratory of the Survey as is of special or general interest. It contains among other matter references to several interesting and some valuable minerals new to Canada, as Hessite, Petzite, Stromeyerite, Bismite, and Smithsonite.

Lastly, the Annual Report for 1895, for Mineral Statistics and Mines, by E. D. Ingall and L. L. Brophy, 1896. The Mineral Production of Canada for 1894 is valued at 20,950,000 dollars; and for 1895 at 22,000,000 dollars; the increase being due chiefly to copper, gold, lead, platinum, and silver. Some comparative, diagrammatic tables, showing the relative production of asbestos, coal, iron, phosphate, gold, and salt, for a series of years, enhance the value of the numerous numerical tables relating to these and other mineral products. A good Index, as usual, completes the volume of reports.

T. R. J.

V.—First Annual Report of the Geological Commission of the Cape of Good Hope for 1896. (Cape Town, 1897.)

THE First Annual Report of the Geological Commission of Cape Colony, now to hand, will be welcomed by all interested in South African Geology.

At present the staff is very small, consisting only of three members. There are two Assistant Geologists, Messrs. A. W. Rogers and E. H. L. Schwarz, while Dr. Corstorphine gives his partial services as Geologist.

Besides the record of field-work for 1896, the Report includes an account of the Cango Caves, and reports on the Laingsburg Coal, and of the subcommittee on deep artesian well-borings. The publication of the Geological Map of the area so far surveyed, on the scale of 800 Cape roods to the inch (half an inch to the mile), with detailed accounts of the work done, will be looked forward to with interest.

During the year 1896 large portions of the following districts have been mapped by Messrs. Rogers and Schwarz: Cape, Stellenbosch,

Malmesbury, Paarl, Tulbagh, Ceres, Worcester, Caledon, and Beaufort West.

In the south-west districts Mr. Rogers proves conclusively the unconformity of the Table Mountain Sandstone on the Malmesbury beds. In the Caledon district he confirms the reading of Mr. Bain that the beds marked as Malmesbury on Dunn's map (1887) are in reality of Bokkeveld (Devonian) age.

The sedimentary rocks around Beaufort West are all ascribed by Mr. Schwarz to the Karoo beds, and not to the Stormberg, as Dunn formerly supposed. The intrusive dolerites in the Karoo beds of Beaufort West are considered to be similar to the Palisade traps of New Jersey and New York.

The most important geological results are those that have been obtained during the present survey of the Tulbagh, Worcester, and Prince Albert districts. At Worcester a very large exposure of Ecca beds is described in contact with Malmesbury beds, a fault being suggested by Mr. Schwarz for this unusual relationship.

This confirmation of older observers of the existence of Karoo beds outside the prescribed limits of the Karoo Basin will be a surprise to many who are wedded to the idea of the simplicity in structure of South African geology. But a complete revolution in the reading of South African stratigraphy will startle no one personally acquainted with its present unsatisfactory state. In the area examined so far, the conformity of the Dwyka conglomerate and Zwartebergen group is agreed upon. This view is in direct opposition to that of the late Professor Green, but accords with the diagram section of the Prince Albert region by Mr. Sawyer.[1]

The theory of the glacial origin of the Dwyka conglomerate receives the support of the Commission, further evidence, in the shape of scratched stones, being brought forward.

Brief notes on the complicated regions of the Witzenbergen, Schurftenbergen, Hex River Mountains, and Langebergen, are supplied by Mr. Schwarz. The strata, from the Table Mountain Sandstone to the Ecca, are considered as being arranged in three main systems of folds conforming to the S-shaped curve.

Between the Schurftenbergen and Hex River Mountains the mass of the Zwartebergen beds is described as being thrust southwards, and many complexities of structure are hinted at. Again, near Verkeerde Vley the Zwartebergen group is said to be faulted against Table Mountain Sandstone, while north of the Gydo Mountains, in the Ceres district, the top of the Dwyka is faulted against the base of the Zwartebergen group.

This description of faulting, folding, and juxtaposition of rocks of various ages betokens a highly complicated region, and it is to be hoped that it will be examined in the greatest possible detail.

W. Gibson.

[1] Report upon the Geology and Mineral Resources of the Division of Prince Albert and surrounding district, by A. R. Sawyer, Capetown, 1893.

CORRESPONDENCE.

FRESH-WATER OSTRACODS IN THE LOWER CARBONIFEROUS SERIES OF AYRSHIRE.

SIR,—On Friday last I found a bed of fresh-water Ostracoda, in the strata exposed in the Gurdy cutting of the railway from Giffen to Kilbirnie.

The beds exposed are as follows:—

	ft.	ins.
Highest *marine* limestone seen in the cutting.		
Black shale, tough	1	8
Dark shale	0	8
Dark shale crowded with fresh-water Ostracoda	0	9
Dark shale	1	6
Sandstone with *Stigmaria*	3	6
Thick bed of dark shale with abundance of *marine* fossils.		
Limestone with *marine* fossils.		

Many of the Ostracoda are filled with *pyrites*, but the valves are *calcareous*; and they often fall off when touched with the point of a needle. The carapaces are usually white, giving the shale a sandy appearance; sometimes they are brown. They occur mostly as single valves.

I believe this is the first time that fresh-water Ostracoda have been found in connection with the marine limestones of Ayrshire. The position of the beds is in the upper part of the Lower Carboniferous Limestone Series of Ayrshire.

Mr. Robert Craig has described the strata of the Gurdy cutting in the Trans. Geol. Soc. Glasgow, vol. ix, p. 64. J. SMITH.

MONKREDDING KILWINNING, *Sept.* 20, 1897.

TRINUCLEUS SETICORNIS.

SIR,—Mr. Marr's letter requires a final answer. When a fossil is not recorded from a certain horizon it is naturally believed that it has really not been found on that horizon. It is almost needless to say that when subsequent research proves an earlier statement to be wrong we consider that the author of it made an unavoidable mistake — unavoidable because of the imperfect knowledge of that time, but a mistake nevertheless in the light of present knowledge. Such mistakes must, of course, be frequent in the progress of any science, particularly in the case of the range of fossils. With regard to the range of the species in question, I have declined to be drawn into an argument, because I find several distinct forms are included under this name by different authors. F. R. COWPER REED.

CAMBRIDGE, *October* 4, 1897.

A QUESTION OF NOMENCLATURE: CHEMICAL NAME FOR H_2O.

SIR,—In writing of the volatile constituents of an igneous magma, paste, or lava, of which the gas of H_2O forms the greater and most important part, I do not know what term should be used in ordinary parlance, as such words as water, water-gas, steam, vapour, simply imply definite physical states of H_2O. Now in a lava under moderate pressure H_2O may exist as steam in the form of bubbles

scattered through it, but under a sufficiently high pressure it is dissolved in the paste or magma, and then it is neither steam, vapour, or water, though frequently spoken of as such. It seems to me that we have no reason to consider it otherwise than an oxide of hydrogen, and that we should speak and write of *Hydrogen oxide or Hydric oxide dissolved in the magma.* Up to the present I have got over the difficulty by writing and speaking of it as H_2O, but such gives me the feeling of looking pedantic on paper or sounding queer in words. I should be grateful, therefore, for any expression of opinion as to why *Hydric oxide* would not do, and any suggestion for a better term. H. J. Johnston-Lavis.

Beaulieu, A.-M., France, *Sept.* 29, 1897.

OBITUARY.

JAMES WINDOES, OF CHIPPING NORTON.

Born 1839. Died Sept. 26, 1897.

We regret to record the death, at the age of 58, of the enthusiastic collector of fossils, James Windoes. Born at Woodstock in 1839, he settled in Chipping Norton some thirty years ago, during the whole of which time he was employed in the glove manufactory of Messrs. B. Bowen and Son. From childhood he manifested a great interest in fossils, but having no advantages of education, he had to pursue his studies entirely unaided. All his spare time was devoted to the search after and study of fossils, and probably no man living had a minuter knowledge of the strata and their organic remains in this part of Oxfordshire. Although of an exceedingly retiring disposition, yet he was always pleased to show his collection to anyone interested in it. Probably few people in Chipping Norton were aware that in a cottage in Albion Street could be seen a collection of fossils and antiquities, unique in its way; but Mr. Windoes was well known to the late Professor Phillips and Mr. T. Beesley, as well as to Mr. Hudleston, Mr. E. A. Walford, and others, who have acknowledged the valuable assistance rendered by him.

When the railway was constructed between Banbury and Cheltenham, Mr. Windoes obtained a fine series of fossils from the junction-beds of the Lower and Middle Lias. The specimens of *Cypricardia intermedia* were exceptionally well preserved. Again, at Hook Norton in the Upper Lias, and at Chipping Norton in various divisions of the Inferior and Great Oolites, he worked long and zealously, obtaining many fossils, and notably fine examples of *Trigonia signata* from the Inferior Oolite of Heythrop. Another species obtained from this formation was named *Trigonia Windoesi* by Dr. Lycett.

Notwithstanding his somewhat humble circumstances, Mr. Windoes could not be induced to dispose of any of his duplicate fossils otherwise than by gift or exchange. The present writer (who is indebted for some of the above particulars to the *Banbury Guardian* of September 30) well remembers the difficulty he at first had in procuring some specimens for the Museum of Practical

Geology, but an exchange was ultimately arranged by means of Geological Survey publications and some recent specimens of *Trigonia*, which latter especially gave great joy to Mr. Windoes. He was a true lover of Nature, worthy to rank with Robert Dick, of Thurso, and others, who, by patient industry and with little or no local encouragement, have rendered good service to geological science.

H. B. W.

MISCELLANEOUS.

Geological Survey.—We regret to learn that Mr. W. W. Watts, M.A., F.G.S., who joined the staff of the Geological Survey in 1891, has just resigned his position of "Temporary Assistant Geologist." The experience which he brought to the Survey from his intimate acquaintance with the Lower Palæozoic and Igneous rocks of Shropshire and the Welsh borders, the subsequent large acquaintance which he made with the Igneous and Sedimentary rocks of Ireland, and with the fine Rock-collection in the Museum at Jermyn Street; his detailed examination of rocks from many areas in England and Wales, and his special study of the older rocks of Charnwood Forest, combined to give him a knowledge that must have been invaluable to the Survey. His loss to the Service is deplorable on this account alone, to say nothing of his readiness at all times to give advice and assistance to others. Mr. Watts has now become Assistant Professor of Geology at the Mason College, Birmingham, where he will have a fine field for work in co-operation with Professor Lapworth.

On the Possible Identity of *Bennettites*, *Williamsonia*, and *Zamites gigas*.—Mr. A. C. Seward, M.A., F.G.S., brings forward evidence[1] in support of the organic connection between *Williamsonia* and the Cycadean fronds known as *Zamites gigas*, L. and H., and in favour of the close relationship, if not identity, of Carruthers' genera *Bennettites* and *Williamsonia*. In the earliest descriptions of the Jurassic inflorescence known as *Williamsonia*, Williamson and other authors regarded the genus as the fructification of the plant which bore the leaves known as *Zamites gigas*. In 1875 Saporta expressed himself strongly against the generally accepted view as to the union of *Williamsonia* and *Zamites*. A recent examination of a series of specimens in the Paris Natural History Museum and elsewhere has convinced the author that *Williamsonia* and *Zamites gigas* are parts of the same plant. Evidence had been previously brought forward of the practical identity of *Williamsonia* and *Bennettites*. More recently acquired information leads to the conclusion that we are now familiar, not only with the nature of the Bennettitian type of inflorescence, but also with the character of the fronds which were, in some instances, associated with this Jurassic fructification. In view of the facts before us, it is advisable that the generic name *Williamsonia* should be substituted for the provisional and comprehensive term *Zamites* as the more suitable generic name of Lindley and Hutton's species *Zamites gigas*.

[1] Brit. Assoc. Meeting, Toronto, 1897: Sect. C (Geology).